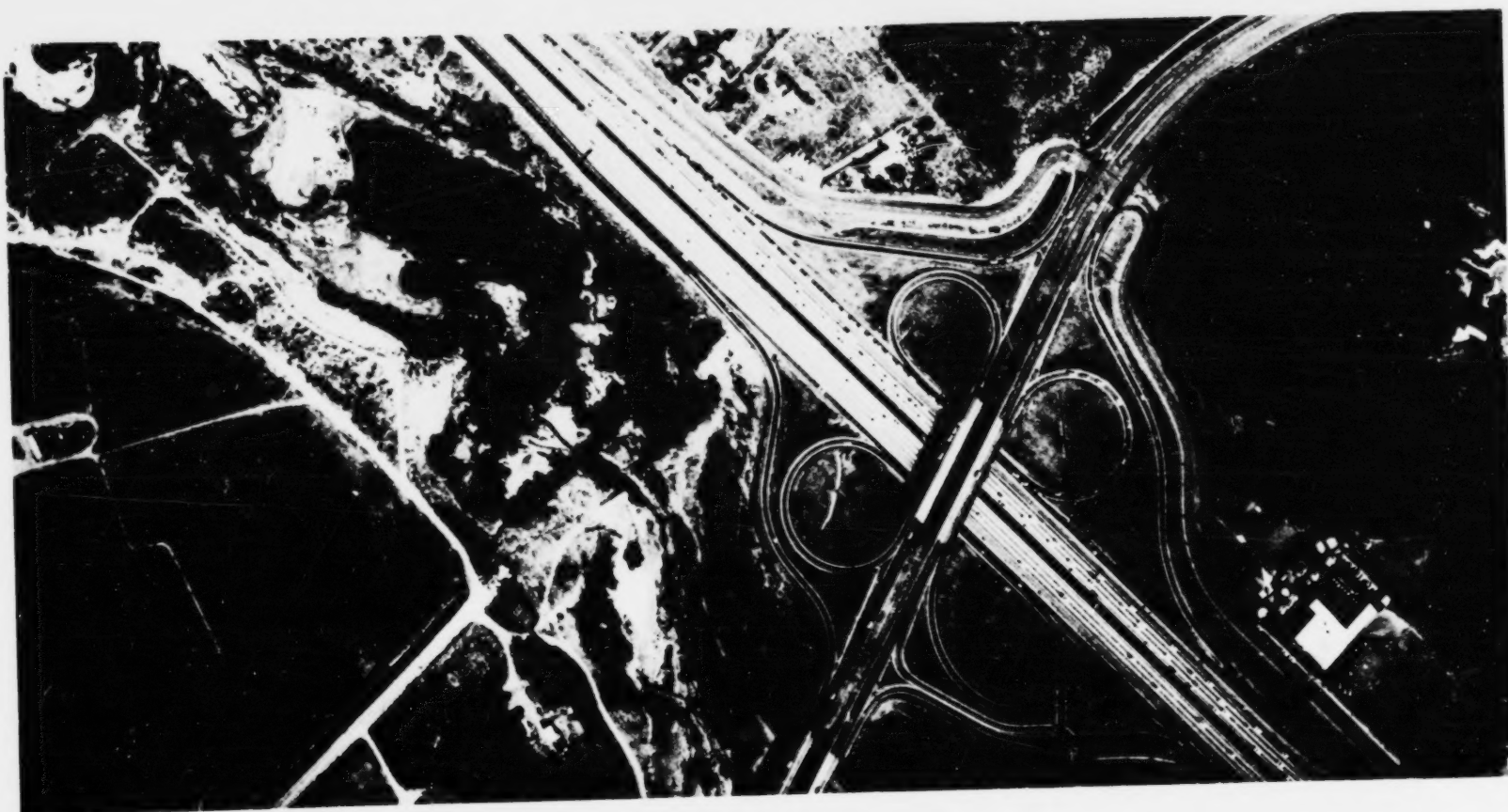




A SURVEY OF AVERAGE DRIVING PATTERNS
IN THE HOUSTON URBAN AREA

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A SURVEY OF AVERAGE DRIVING PATTERNS
IN THE HOUSTON URBAN AREA

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August 29, 1969

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The Houston Chronicle

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Project Manager

INTRODUCTION

System Development Corporation (SDC) has performed a study to survey the characteristic use patterns of privately operated automobiles in the Houston, Texas urban area. The study was conducted under jointly sponsored research contracts to the National Center for Air Pollution Control, Department of Health, Education, and Welfare, and the Coordinating Research Council, Inc. The purpose of the study was to obtain data necessary to develop a composite average driving pattern that would serve as a basis for designing new test cycles for vehicle emission control devices.

During the study SDC installed automatic information recording devices -- called Tachographs -- in 99 privately operated automobiles volunteered by Houston area residents. The data records from these instruments as well as information obtained from log books maintained by each of the volunteer participants have been reduced and analyzed. This document presents a discussion of the study results, and a comparison of these results with the findings of a similar survey conducted previously in Los Angeles, California.

This report is published as Volume I of SDC document series TM-(L)-4119. Volume 0, A Survey of Average Driving Patterns in the Los Angeles Urban Area presents in addition to the Los Angeles survey findings a description of the survey technique as well as the data reduction and statistical analysis procedures. Since the technique and procedures used for collecting and analyzing the Houston data are essentially the same as those employed for Los Angeles, reference is made to Volume 0 for information in these areas.

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RESULTS OF STUDY

This chapter presents the results of the Survey of Average Driving Patterns in the Houston urban area. The results are organized into three sections. The first presents a detailed description of the several average or typical¹ driving patterns that were developed from a statistical analysis of the survey data. The second section presents a summary description of the data base from which the typical patterns were derived. The structure of the first two sections of the present report parallels wherever possible the structure of the similar sections in Part I of Volume 0, A Survey of Average Driving Patterns in the Los Angeles Urban Area.² The third section presents a comparison between the Houston results and the results of the Los Angeles survey using statistical analytical techniques to determine similarities and differences between the driving habits of the citizens of two cities.

TYPICAL DRIVING PATTERNS

SDC's intent in deriving the typical driving patterns described below has been to extract from a large amount of information collected during the survey a fairly detailed quantitative and qualitative description of those patterns which clearly stand out as typical. While the data base is large, it is not so large that the analyst can, with great confidence, probe very deeply into the intricacies of secondary or tertiary patterns. Nevertheless, in view of the scarcity of previous results in this area of study, particularly from the standpoint of enlisting the public's aid in the data collection effort, the results presented here present a substantial contribution to our knowledge of automobile utilization--even if they only serve to reinforce what have heretofore been intuitive concepts about how people drive their cars.

¹ SDC prefers the term "typical" to the term "average" since the latter has the connotation of an arithmetic mean which in the present case is not entirely appropriate. The typical driving patterns are, in most aspects of the analysis, derived from modes rather than means in the statistical sense.

² D. H. Kearin, R. L. Lamoureux, A Survey of Average Driving Patterns in the Los Angeles Urban Area, System Development Corporation, TM-(L)-4119/000/01A, June 2, 1969.

A typical driving pattern is described in terms of a day's sequence of trips that all start at approximately the same time, have the same trip segment string (i.e., have identical patterns of freeway and nonfreeway usage), and which sequence of trips can be explained by a reasonable scenario of driver behavior. The patterns described below are those which stand out clearly in the results of the analysis. Part of the description of each pattern is an indication of the percentage of the entire survey sample represented by the pattern as well as the percentage of the n-trip sample which is characterized by the n-trip pattern. Figure 1 shows the distribution of n-trip days for the seven days of the week.

Table 1 shows the distribution of complete weekdays and weekend days¹ upon which survey participants drove their cars on n-trips. In the Houston survey, n varied from zero to 15 on weekdays and from zero to 17 on weekends. The table shows that the occurrence of days on which more than five trips were driven drops off quickly compared to days on which six or less were driven. Partly because of the dropoff in sample size as the number of trips increased, but more importantly because in Houston the potential number of trip patterns increases geometrically as the number of trips per day increases, patterns were discovered only for two-, three-, four-, and five-trip sequences.

No clear-cut patterns were discernible for weekend driving. The time distribution of weekend trips is quite different from that of weekday trips (see Figure 12 & 13). To some extent this difference may be more marked in our survey due to the composition of the survey population. All participants in the survey were contacted through their place of employment. Consequently,

¹ A complete day is one for which data were obtained for the entire day's operation or for which data on two half-days of operation were available and could be merged to make a single day's operation.

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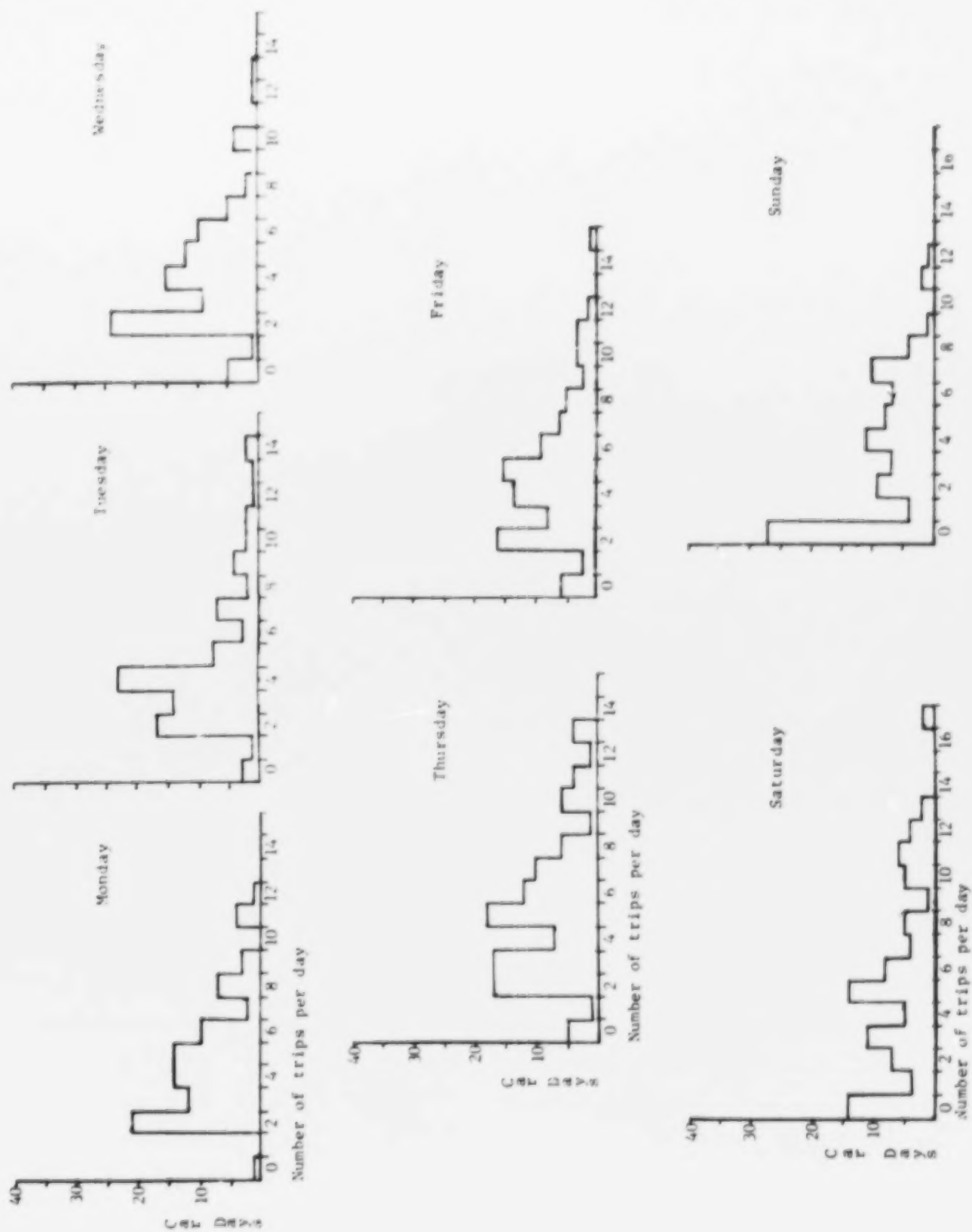


FIGURE 1
FREQUENCY OF N-TRIP DAYS BY DAY OF WEEK

TABLE 1
DAILY DISTRIBUTION OF COMPLETE N-TRIP
DAYS IN HOUSTON DRIVING PATTERNS SURVEY ¹

NUMBER OF TRIPS PER DAY (N)	NUMBER OF N-TRIP DAYS							TOTAL
	M	T	W	TH	F	S	S	
0	1	3	5	5	6	14	27	61
1	0	1	1	1	2	4	4	13
2	21	17	24	17	16	7	9	111
3	12	14	9	7	8	11	7	68
4	14	23	15	18	13	5	11	99
5	14	8	12	12	15	14	8	83
6	10	3	10	10	9	8	7	57
7	2	7	5	6	6	4	10	40
8	7	2	2	1	5	5	4	26
9	3	4	1	6	2	1	1	18
10	0	2	4	4	3	5	0	18
11	4	2	0	1	3	6	1	17
12	1	1	1	4	1	4	2	14
13	0	1	1	0	0	2	1	5
14	0	2	0	0	0	0	0	2
15	0	0	0	0	1	0	0	1
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	2	0	2
TOTAL	89	90	90	92	90	92	92	635

¹In addition, there were nine unmatched half-days (i.e., days on which the Tachograph was installed or removed and for which data from the matching removal or installation day were unavailable). There were two one-trip days, one three-trip day, three four-trip days, two seven-trip days and one eight-trip day in this category.

the daily work schedule imposed upon a working employee tends to be reflected in the survey results. Weekday-weekend differences are discussed more fully in the General Results section of this chapter.

In analyzing the typical n-trip day patterns, differences in the occurrence of particular trip segment strings require that two alternative trips be considered as components of the pattern in certain cases. Also, two distinct patterns for the four-trip day were discovered that require alternative descriptions.

The following sections of the chapter describe each sequence, or pattern, of trips in terms of a scenario and a table of values for such trip descriptors as start time, trip and segment distance, segment average speed, number of momentary stops (idles) per segment, idling time per segment,¹ route types, and purpose of trip. The quantities tabulated for start time, distance, average speed, number of momentary stops (idles), idling time, route type and purpose of trip are the mean values associated with trips and segments that are defined by the specified time slot, purpose, and trip segment string. Adjacent to these values are ranges within which at least 75 percent of the data lie. These ranges are obtained by examining a printout of the distribution of cases for each variable as specified by time slot, purpose, and trip segment string. In the printout, variables are grouped into class intervals. The class intervals used by the program are as follows:

¹ In the Los Angeles Survey a linear regression model was made to convert number of momentary stops to idling time. Because of the wide variance in measured idle time as a function of number of stops, we expressed reservations about this approach in the Los Angeles report. (See D. H. Kearin, R. L. Lamoureux, *op. cit.*, pp. 1-56, 2-18.) In the Houston analysis we have discarded the use of the regression model and have included as idling time only that which was actually recorded on the Tachograph disc (i.e., the summation of all idling periods in excess of 40 seconds). Therefore, in evaluating idle time figures, one must consider both the number of momentary stops, which indicate the extent of short idling periods of indeterminant length, and the mean idling time, which represents the expected value of any extended period of idling.

Distance: 3-mile intervals from 0 miles to 50 miles.

Average speed: 5-mph intervals from 0 mph to 75 mph.

Momentary stops: 2-stop intervals from 0 to 30 stops.

Idling time: 2-minute intervals from 0 to 10 minutes.

To calculate the 75-percent ranges for distance, speed, and idling time, the analyst starts with the class interval that contains the mean, and working away from that interval in both directions, sums the number of cases until he has included at least 75 percent of them. The number he accumulates in each direction depends on the way the data are distributed: For distributions skewed in the lower direction, more cases will be picked up below the mean; for symmetrical distributions, the range will be fore balanced. The time slots used for grouping the data were agreed upon earlier by CRC¹ and SDC. Weekdays are divided into eight time slots, weekend-days into six. Table 2 shows the organization of the time slot structure.

TABLE 2
TIME SLOT STRUCTURE USED IN
HOUSTON DRIVING PATTERNS SURVEY

TIME SLOT NUMBER	TIME PERIOD (24 HOUR CLOCK)	
	WEEKDAY	WEEKEND
1	0000-0559	0000-0829
2	0600-0859	0830-1059
3	0900-1129	1100-1259
4	1130-1329	1330-1759
5	1330-1629	1800-2059
6	1630-1829	2100-2359
7	1830-2059	—
8	2100-2359	—

¹ CRC-APRAC Project Groups CAPE-5 and CAPE-10.

The time distribution of all trip start times is shown in Figures 12 and 13 in the General Results section of this chapter.

The elapsed time for each component trip of a typical trip pattern is based on completing the mean trip or segment distance at the mean average speed. The reason for calculating mean elapsed time from mean distance and mean average speed is twofold. First, as described in the pattern descriptions, certain trip distances are derived artificially so that no data on real elapsed time over these distances are available. Second, and more important, the Tachograph provides distance and elapsed time for each trip from which exact average speed values are calculated. The values of these three variables are, however, continuously distributed from the standpoint of the computer. In order to meet computer storage requirements and to obtain distribution information, these variables must be grouped or classified into the class intervals previously listed. Once this is done, mean speed, mean trip distance and mean elapsed time are no longer functionally related in exact terms since all calculations use the midpoint of the class interval to represent all values within that interval. Therefore, the authors believe that the average speed and average distance are more "real" intuitively since they are descriptive of actual, not artificial, phenomena that occurred during the survey, and that elapsed time can best be calculated using the mean values for these variables rather than using the mean values for time and distance to calculate mean average speed. Variations over the ranges for distance and speed will, of course, cause differences in the elapsed time of the trip or segment.

A general description of the method used in deriving these patterns is contained in the Statistical Analysis section of Part III of the Los Angeles report.¹ The section on general results that follows the description of the typical trip patterns discusses in greater detail the quantitative basis for the patterns described.

¹ Ibid., pp. 3-1 to 3-16.

The Two-Trip Day

Figure 2 shows the time dependency distribution of all two-trip weekdays that occurred during the survey period in Houston. The presentation is in the form of a trip-to-trip transition matrix. The matrix is set up as follows: All trips are assigned a time slot value based on the time slot into which one-half or more of the total trip time falls. These time slot values for all trips one and two on two-trip days were analyzed to determine into which cell of the trip-to-trip transition matrix the day's record would be counted. The time slot value for trip one established the row for the entry, the time slot value for trip two established the column. Therefore, if a trip one occurred in time slot two followed by a trip two in time slot six, the record for that day was associated with cell 26 at the intersection of the second row and the sixth column. In addition to the slot dependencies, the analysis also provided counts for purpose-to-purpose dependencies within each time slot cell. It is from these latter dependencies that the literal entries in Figure 2 indicating the typical purpose-to-purpose pairs are obtained. In Figure 2 and subsequent trip-to-trip transition matrices these literal entries are made only for cells with high frequency trip entries and then only if a particular purpose pair stands out.

From Figure 2, we see that the highest frequency count occurs in cell 26 with 71 two-trip days showing the transition. Of these 71, 69 show the purpose-to-purpose combination of a trip one, to work, followed by a trip two, to home. That this is a typical trip pattern is clear. Reinforcement is added by the fact that five trips in the adjacent cell 25 as well as five trips in cell 27 show the same purpose-to-purpose structure. If one assumes that the five in cell 25 represent people with early quitting times, say between 4:00 and 4:30 p.m., while the five in cell 27 represent overtime workers, then the analysis shows that between 61 out of 95 (64%) and 82 out of 95 (86%) of the two-trip days fit our typical pattern. This range represents between 13.5% and 18.1% of the total complete car-weekdays in the survey.

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TO TIME SLOT		0000-0559	0600-0859	0900-1129	1130-1329	1330-1629	1630-1829	1830-2059	2100-2359	
FROM TIME SLOT	0000-0559	0	0	0	0	0	0	0	0	
	0600-0859		0	0	0	8	71 W-H	8	1	
				0900-1129	1	0	0	0	2	1
					1130-1329	0	0	0	0	1
						1330-1629	0	0	0	0
TRIP ONE TO TRIP TWO							1630-1829	0	0	1
TOTAL TWO-TRIP WEEKDAYS: 95								1830-2059	1	0
LEGEND									2100-2359	0
H - Home		S - Shopping								
W - Work		C - Church, School, etc.								
B - Business		R - Recreation								

FIGURE 2

TWO-TRIP WEEKDAY TRANSITION MATRIX

The values for the typical two-trip pattern are shown in Table 3. In the first column, entitled Trip Number, the letter "A" represents a nonfreeway trip while the letter "B" represents a freeway trip. The trip-to-work in time slot two is more likely to have a trip segment sequence of nonfreeway only rather than nonfreeway/freeway/nonfreeway (the survey contained 214 of the former, 109 of the latter). However, because a substantial number of work trips in this time period do have the nonfreeway/freeway/nonfreeway configuration, we believe that both should be accounted for. The Houston data tend to indicate that weighting factors of two-thirds and one-third should be assigned respectively to the N and the NFN trip segment string work trips in time slot two. This weighting assignment is also used in the subsequent three-, four-, and five-trip day patterns. The data for return trips home in time slot six are confused by the incidence of return trips from origination points other than work. Realizing that the decision is arbitrary, we have chosen to assign the same structure to the return trip from work that is shown in the morning trip to work. Therefore, the distances shown in Table 3 for the evening trip are the same as those in the morning trip. The average speeds for both trips, however, are those characteristic of the time slot, purpose, and trip segment string described. The elapsed times are calculated from these values.

The Three-Trip Day

Figures 3 and 4 show the two trip-to-trip transition matrices for complete three-trip days in the Houston survey. The matrix in Figure 3 shows the transition from trip one to trip two; that in Figure 4 from trip two to trip three.

The predominant transition in the first matrix is from a first trip in time slot two to a second trip in time slot six. In addition, there are transitions of a secondary importance for the adjacent cells representing second trips in time slots five and seven. Of the total of 21 trips in cell 26, 14 represent

TABLE 3
THE TYPICAL TWO-TRIP DAY PATTERNS
(REPRESENTS 64% - 86% OF ALL TWO-TRIP DAYS, 13.5% - 18.1% OF ALL COMPLETE CAR-WEEKDAYS)

TRIP NUMBER	PURPOSE	SEGMENT NUMBER	ROUTE TYPE	START TIME		MEAN ELAPSED TIME (MIN)	DISTANCE (MILES)		AVERAGE SPEED (MPH)		NUMBER OF STOPS (IDLES)		IDLE TIME (MIN)	
				MEAN	RANGE*		MEAN	RANGE**	MEAN	RANGE**	MEAN	RANGE**	MEAN	RANGE**
1A	WORK	1	NF	0721	0650 - 0752	21.4	8.3	0.1 - 12.0	23.3	10.0 - 35.0	9.3	0.0 - 13.0	1.7	0.0 - 3.0
1B	OR:													
	WORK	1	NF	0715	0638 - 0742	8.2	3.1	0.1 - 9.0	22.7	10.0 - 35.0	4.0	0.0 - 8.0	1.6	0.0 - 2.0
	2	F			11.4	6.3	3.0 - 12.0	33.3	20.0 - 45.0	1.0	0.0 - 2.0	0.6	0.0 - 1.0	
		3	NF			9.1	3.6	0.1 - 9.0	23.7	5.0 - 30.0	5.0	0.0 - 8.0	0.8	0.0 - 1.0
						28.7	13.0				10.0		3.0	
TRIPS 1A AND 1B OCCUR IN THE RATIO OF 2 TO 1 RESPECTIVELY														
2A	HOME	1	NF	1719	1642 - 1753	21.1	8.3	0.1 - 12.0	23.6	15.0 - 35.0	6.9	0.0 - 12.0	1.0	0.0 - 2.0
2B	OR:													
	HOME	1	NF	1709	1637 - 1741	9.9	3.6	0.1 - 9.0	21.9	10.0 - 30.0	4.9	0.0 - 8.0	0.9	0.0 - 1.0
	2	F			11.4	6.3	3.0 - 12.0	33.1	15.0 - 45.0	0.5	0.0 - 2.0	0.5	0.0 - 1.0	
		3	NF			7.0	3.1	0.1 - 9.0	26.5	10.0 - 35.0	4.5	0.0 - 8.0	0.6	0.0 - 1.0
						28.3	13.0				9.9		2.0	
TRIPS 2A AND 2B OCCUR IN THE RATIO OF 2 TO 1 RESPECTIVELY														

* RANGE EQUALS MEAN PLUS OR MINUS ONE STANDARD DEVIATION

** RANGE CONTAINS AT LEAST 75% OF ALL CASES (SEE TEXT)

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TO TIME SLOT		0000-0559	0600-0859	0900-1129	1130-1329	1330-1629	1630-1829	1830-2059	2100-2359	
FROM TIME SLOT	0000-0559	0	0	0	0	0	0	0	0	
	0600-0859		7	0	1	7	21 W-S	5	1	
				0900-1129	1	1	1	1	0	0
					1130-1329	2	1	0	0	0
						1330-1629	0	0	0	0
							1630-1829	0	1	0
								1830-2059	0	0
									2100-2359	0

TRIP ONE TO TRIP TWO

TOTAL THREE-TRIP WEEKDAYS: 50

LEGEND

H - Home	S - Shopping
W - Work	C - Church, School, etc.
B - Business	R - Recreation

FIGURE 3

THREE-TRIP WEEKDAY TRANSITION MATRIX

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TO TIME SLOT		0000-0559	0600-0859	0900-1129	1130-1329	1330-1629	1630-1829	1830-2059	2100-2359
FROM TIME SLOT	0000-0559	0	0	0	0	0	0	0	0
	0600-0859	1	0	1	1	3	1	0	
	0900-1129		0	1	0	0	0	0	
	1130-1329			0	3	0	1	0	
	1330-1629				2	7	0	0	
	1630-1829					15 S-H	6	1	
	1830-2059						6	0	
	2100-2359							1	

TRIP TWO TO TRIP THREE
TOTAL THREE-TRIP WEEKDAYS: 50

LEGEND
H - Home S - Shopping
W - Work C - Church, School, etc.
B - Business R - Recreation

FIGURE 4

THREE-TRIP WEEKDAY TRANSITION MATRIX

the purpose-to-purpose transition of work to shopping. In addition, three of the trips in cell 25 and four in cell 27 also have this pattern. This morning-to-evening, work-to-shopping pattern between trips one and two therefore represents between 28% and 42% of all three-trip days in the Houston survey.

The second matrix, Figure 4, shows the highest frequency of transitions between trips two to three occurring within time slot six. Secondary patterns also occur in cells 52, 67 and 77 which correlate with the overall three-trip day pattern. In cell 66, 11 transitions out of 15 are from shopping to home; in cell 52, three out of seven; in cell 67, four out of six; and in cell 77, six out of six. Therefore, we believe it reasonable to state that the three-trip day pattern represents approximately 45% of the three-trip days (between 21 and 24 out of 50 such days), or 5.0% of the complete car-weekdays in the survey.

Table 4 contains the values describing the typical three-trip day pattern. In calculating results for the trips 2A-3A combinations, the total distance of trip 1A is allocated between trips 2A and 3A in proportion to the mean distances of shopping trips and home trips in time slot six.

The distribution of trip purposes and trip segment strings in time slot six provides no grounds for determining whether the evening shopping trip for drivers who use freeways between work and home typically has the configuration of N or NFN. There are 85 of the former and 22 of the latter. The "expected" number¹ of the former is 78 and of the latter is 18. Because there are no clear-cut grounds for decision, two trip combinations are shown in Table 4, labeled 2B1-3B1 and 2B2-3B2. In the first, the shopping trip has the

¹ The "expected" number is determined by applying a chi-square test to the tableau showing purpose-trip segment string frequencies by time slot. The underlying assumption is that such a test indicates the degree to which purpose-trip segment string combinations depart from independence of time slot. For a more complete explanation, see *ibid.*, p. 1-37, 1-40.

TABLE 4
THE TYPICAL THREE-TRIP DAY PATTERNS
(REPRESENTS 45% OF ALL THREE-TRIP DAYS, 5.0% OF ALL COMPLETE CAR-WEEKDAYS)

TRIP NUMBER	PURPOSE	SEGMENT NUMBER	ROUTE TYPE	START TIME		MEAN ELAPSED TIME (MIN)	DISTANCE (MILES)		AVERAGE SPEED (MPH)		NUMBER OF STOPS (IDLES)		IDLE TIME (MIN)	
				MEAN	RANGE*		MEAN	RANGE**	MEAN	RANGE**	MEAN	RANGE**	MEAN	RANGE**
1A	WORK OR: SHOP	1	MF	0721	0650 - 0752	21.4	8.3	0.1 - 12.0	23.3	10.0 - 35.0	9.3	0.0 - 13.0	1.7	0.0 - 3.0
1B	WORK	1	MF	0715	0638 - 0742	8.2	3.1	0.1 - 9.0	22.7	10.0 - 35.0	4.0	0.0 - 8.0	1.6	0.0 - 2.0
		2	F			11.4	6.3	3.0 - 12.0	33.3	20.0 - 45.0	1.0	0.0 - 2.0	0.6	0.0 - 1.0
		3	MF			9.1	3.6	0.1 - 9.0	23.7	5.0 - 30.0	5.0	0.0 - 8.0	0.8	0.0 - 1.0
TRIPS 1A and 1B OCCUR IN THE RATIO OF 2 TO 1 RESPECTIVELY						28.7	13.0			10.0		3.0		
2A	SHOP	1	MF	1724	1650 - 1758	7.2	3.0	0.1 - 4.0	25.1	15.0 - 35.0	4.7	0.0 - 8.0	0.6	0.0 - 1.0
3A	HOME	1	MF	1754		13.5	5.3	0.1 - 8.0	23.6	15.0 - 35.0	4.3	0.0 - 8.0	0.6	0.0 - 1.0
2B1	SHOP	1	MF	1724	1650 - 1758	6.6	2.7	0.1 - 6.0	25.1	15.0 - 35.0	4.2	0.0 - 8.0	0.5	0.0 - 1.0
3B1	HOME	1	MF	1754		2.5	0.9	0.1 - 3.0	21.9	10.0 - 30.0	1.2	0.0 - 2.0	0.2	0.0 - 1.0
		2	F			11.4	6.3	3.0 - 12.0	33.1	15.0 - 45.0	0.5	0.0 - 2.0	0.5	0.0 - 1.0
		3	MF			7.0	3.1	0.1 - 9.0	26.5	10.0 - 35.0	4.5	0.0 - 8.0	0.6	0.0 - 1.0
						20.9	10.3			6.2		1.3		
2B2	SHOP	1	MF	1724	1652 - 1800	8.0	3.6	0.1 - 9.0	27.0	10.0 - 35.0	3.6	0.0 - 6.0	1.3	0.0 - 3.0
		2	F			10.2	6.3	3.0 - 12.0	36.9	25.0 - 50.0	0.3	0.0 - 2.0	0.5	0.0 - 1.0
		3	MF			5.2	2.1	0.1 - 5.0	24.2	10.0 - 40.0	2.2	0.0 - 4.0	0.6	0.0 - 1.0
						23.4	12.0			6.1		2.4		
3B2	HOME	1	MF	1812		2.5	1.0	0.1 - 3.0	23.6	15.0 - 35.0	0.9	0.0 - 2.0	0.2	0.0 - 1.0
TRIP COMBINATIONS 2A-3A, 2B1-3B1, AND 2B2-3B2 OCCUR IN THE RATIO OF 4 TO 1 TO 1 RESPECTIVELY														

* RANGE EQUALS MEAN PLUS OR MINUS ONE STANDARD DEVIATION

** RANGE CONTAINS AT LEAST 75% OF ALL CASES (SEE TEXT)

configuration N and the subsequent home trip has the configuration NFN. In the second combination, the sequence is reversed: each combination is weighted equally at one-sixth apiece. In both cases, the distance allocated to the shopping trip is the mean distance for shopping trips with the particular trip segment string shown and within the distance range for that particular segment of the morning work trip of which the shopping trip is a part. The subsequent home trip is assigned a distance equal to the difference between the shopping trip and the morning work-to-home trip. As in the two-trip day, we realize that assigning equal distances to the home-to-work and the work-to-home trip is arbitrary, but there is no better criterion provided by the data.

Given the distance assignments just described, the average speed used in continuing the calculations for each trip combination is that of the particular trip segment string for time slot six. Elapsed times depend on completing the assigned distance at the assigned average speed. Unfortunately, momentary stops and idling times are allocated in the same manner as trip distance. Start times for trips 3A, 3B1 and 3B2 are obtained by adding the mean elapsed time between trips for values under one hour. As in the Los Angeles survey, the value added is 23 minutes. No range is shown for the start time value obtained this way.

The Four-Trip Day

Figures 5 through 7 show the three trip-to-trip transition matrices for the four-trip day. Two typical patterns for the four-trip day were discovered: The first is distinguished by a pair of trips in the evening, the second by a pair of trips during the noon period.

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TO TIME SLOT		0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359
FROM TIME SLOT	0000- 0559	1	1	0	0	2	0	0	0
	0600- 0859		4	4	18 W-S W-B	8	34 W-H	2	1
			0900- 1129	2	1	0	1	1	0
				1130- 1329	1	0	0	0	0
					1330- 1629	0	1	0	0
						1630- 1829	1	0	0
							1830- 2059	0	0
								2100- 2359	0

TRIP ONE TO TRIP TWO
TOTAL FOUR-TRIP WEEKDAYS: 83

LEGEND
H - Home S - Shopping
W - Work C - Church, School, etc.
B - Business R - Recreation

FIGURE 5

FOUR-TRIP WEEKDAY TRANSITION MATRIX

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TO TIME SLOT		0000-0559	0600-0859	0900-1129	1130-1329	1330-1629	1630-1829	1830-2059	2100-2359
FROM TIME SLOT	0000-0559	0	1	0	0	0	0	0	0
	0600-0859		0	0	0	2	3	0	0
	0900-1129			1	3	1	1	0	0
	1130-1329				12 S-W B-W	7	0	1	0
	1330-1629					5	2	3	0
	1630-1829						19 H-S H-R	18 H-R H-S	0
	1830-2059							3	0
	2100-2359								1

TRIP TWO TO TRIP THREE
TOTAL FOUR-TRIP WEEKDAYS: 83

LEGEND
H - Home S - Shopping
W - Work C - Church, School, etc.
B - Business R - Recreation

FIGURE 6

FOUR-TRIP WEEKDAY TRANSITION MATRIX

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TO TIME SLOT		0000-0559	0600-0859	0900-1129	1130-1329	1330-1629	1630-1829	1830-2059	2100-2359
FROM TIME SLOT	0000-0559	0	0	0	0	0	0	0	0
	0600-0859		0	0	0	0	1	0	0
			0900-1129	0	0	0	1	0	0
				1130-1329	1	0	14 W-H	0	0
					1330-1629	3	7	2	3
						1630-1829	16 S-H	5	4
							1830-2059	15 S-H	10 R-H
								2100-2359	1

TRIP THREE TO TRIP FOUR
TOTAL FOUR-TRIP WEEKDAYS: 83

LEGEND
H - Home S - Shopping
W - Work C - Church, School, etc.
B - Business R - Recreation

FIGURE 7
FOUR-TRIP WEEKDAY TRANSITION MATRIX

Evening Pattern

Cell 26 in Figure 5 shows that 34 cars transitioned from time slot two to time slot six. Of these, 25 transitioned from a work trip to a home trip. Turning to Figure 6, we see that of the 25 cars that transitioned home in time slot six from time slot two, 24 in turn transitioned to third trips in time slots six and seven. Of these third trips in time slot six, nine were shopping trips, four were recreation. Third trips in time slot seven included four shopping trips, two school trips and five recreation trips. Figure 7 shows that third trips in time slot six transitioned primarily to fourth trips in time slot six and third trips in time slot seven transitioned to time slots seven and eight. Of the 16 of these fourth trips in time slot six (cell 66), 12 were return trips from shopping. Of the 15 fourth trips in time slot seven (cell 77), 10 were return trips from shopping, 3 were return trips from recreation. Of the 10 fourth trips in time slot eight (cell 78), one returned from shopping, two from school and seven from recreation.

From these data we deduce the typical Four-Trip Day (Evening) Pattern, shown in Table 5. Trip one is to work in time slot two. Trip two returns home in time slot six. Trip three is a shopping, recreation or school trip in time slot seven. Trip four returns home in the same time slot. Trips one and two are divided between the two-trip segment structures used in the previous two patterns in the same two-to-one ratio. The trip segment structures of the evening trips are divided between nonfreeway and nonfreeway-freeway-nonfreeway in the ratio of three to one. Both of these trip segment string configurations exceed their "expectations" in time slot seven for the purposes cited. They also occur in the approximate three-to-one ratio used.

The minimum number of car-days that show the typical four-trip evening pattern (summing the shopping, school and recreation trips in time slots six and seven) is 24. This represents 29% of all four-trip days and 53% of all car-weekdays in the survey.

TABLE 5
THE TYPICAL FOUR-TRIP DAY (EVENING) PATTERNS
(REPRESENTS 29% OF ALL FOUR-TRIP DAYS, 5.3% OF ALL COMPLETE CAR-WEEKDAYS)

TRIP NUMBER	PURPOSE	SEGMENT NUMBER	ROUTE TYPE	START TIME		MEAN ELAPSED TIME (MIN)	DISTANCE (MILES)		AVERAGE SPEED (MPH)		NUMBER OF STOPS (IDLES)		IDLE TIME (MIN)	
				MEAN	RANGE*		MEAN	RANGE**	MEAN	RANGE**	MEAN	RANGE**	MEAN	RANGE**
1A	WORK	1	NF	0721	0650 - 0752	21.4	8.3	0.1 - 12.0	23.3	10.0 - 35.0	9.3	0.0 - 13.0	1.7	0.0 - 3.0
1B	WORK	1	NF	0715	0638 - 0742	8.2	3.1	0.1 - 9.0	22.7	10.0 - 35.0	4.0	0.0 - 8.0	1.6	0.0 - 2.0
		2	F			11.4	6.3	3.0 - 12.0	33.3	20.0 - 45.0	1.0	0.0 - 2.0	0.6	0.0 - 1.0
		3	NF			9.1	3.6	0.1 - 9.0	23.7	5.0 - 30.0	5.0	0.0 - 8.0	0.8	0.0 - 1.0
						28.7	13.0				10.0		3.0	
TRIPS 1A AND 1B OCCUR IN THE RATIO OF 2 TO 1 RESPECTIVELY														
2A	HOME	1	NF	1719	1642 - 1753	21.1	8.3	0.1 - 12.0	23.6	15.0 - 35.0	6.9	0.0 - 12.0	1.0	0.0 - 2.0
2B	HOME	1	NF	1709	1637 - 1741	9.9	3.6	0.1 - 9.0	21.9	10.0 - 30.0	4.9	0.0 - 8.0	0.9	0.0 - 1.0
		2	F			11.4	6.3	3.0 - 12.0	33.1	15.0 - 45.0	0.5	0.0 - 2.0	0.5	0.0 - 1.0
		3	NF			7.0	3.1	0.1 - 9.0	26.5	10.0 - 35.0	4.5	0.0 - 8.0	0.6	0.0 - 1.0
						28.3	13.0				9.9		2.0	
TRIPS 2A AND 2B OCCUR IN THE RATIO OF 2 TO 1 RESPECTIVELY														
3A	S, R, C	1	NF	1929	1849 - 2009	6.9	2.9	0.1 - 6.0	25.2	10.0 - 35.0	3.2	0.0 - 4.0	0.7	0.0 - 1.0
4A	HOME	1	NF	1932	1844 - 2030	10.6	4.3	0.1 - 6.0	24.3	10.0 - 35.0	4.2	0.0 - 8.0	0.9	0.0 - 1.0
		2	NF	1912	1835 - 1949	4.6	1.9	0.0 - 3.0	24.7	10.0 - 40.0	2.6	0.0 - 6.0	0.9	0.0 - 1.0
		3	NF			9.8	6.4	2.0 - 18.0	39.0	25.0 - 50.0	0.7	0.0 - 1.0	0.5	0.0 - 1.0
3B	S, R, C	1	NF	1912	1835 - 1949	4.7	2.2	0.0 - 3.0	28.2	10.0 - 35.0	2.4	0.0 - 6.0	0.6	0.0 - 1.0
						19.1	10.5							
4B	HOME	1	NF	1924	1840 - 2008	4.0	1.7	0.0 - 3.0	25.6	10.0 - 40.0	2.5	0.0 - 4.0	0.9	0.0 - 1.0
		2	F			8.4	4.9	0.0 - 9.0	35.1	20.0 - 55.0	0.3	0.0 - 1.0	0.6	0.0 - 1.0
		3	NF			5.3	2.7	0.0 - 6.0	30.5	10.0 - 45.0	2.2	0.0 - 4.0	0.9	0.0 - 1.0
						17.7	9.3							

TRIP COMBINATIONS 3A-4A AND 3B-4B OCCUR IN THE RATIO OF 3 TO 1 RESPECTIVELY
* RANGE EQUALS MEAN PLUS OR MINUS ONE STANDARD DEVIATION

** RANGE CONTAINS AT LEAST 75% OF ALL CASES (SEE TEXT)

Noon Pattern

Cell 24 in Figure 5 shows 18 cars transitioning from a trip in time slot two to a trip in time slot four. All of them transition from a first trip to work, nine of them to a shopping trip, eight to a business trip, and one to a home trip. Under the definition of trip purpose given to survey participants, any of these trips could be to lunch. In Figure 6, cell 44 shows 12 trip twos transitioning to trip threes in time slot four. Ten of these are return trips to work, six from shopping, three from business, and one from home. In addition, cell 45 contains four return trips to work, two from shopping, and two from business.

Cell 46 of Figure 7 shows that 14 third trips in time slot four transition to a fourth trip in time slot six. Eleven of these are from work to home. These data indicate the structure of the typical Four-Trip (Noon) Pattern: trip one is to work, trip two to lunch, trip three back to work, and trip four home in the evening.

The noontime trips are both nonfreeway. The values in Table 6 are obtained by combining and weighting the computed values for the two principal purposes: business and shopping. The morning work trip and the evening return home trip have the same structure as in the other typical patterns and are weighted in the same way.

The minimum number of car-days that showed the Four-Trip Day (Noon) Pattern was 12. This number represents 14% of all four-trip days and 2.7% of all car-days in the sample.

The Five-Trip Day

Figures 8 through 11 contain the trip-to-trip transition matrices for the five-trip day. As noted earlier, as the number of trips per day increases the number of possible trip-to-trip combinations increases geometrically and the

TABLE 6
THE TYPICAL FOUR-TRIP DAY (NOON) PATTERN
(REPRESENTS 14% OF ALL FOUR-TRIP DAYS, 2.7% OF ALL COMPLETE CAR-WEEKDAYS)

TRIP NUMBER	PURPOSE	SEGMENT NUMBER	ROUTE TYPE	START TIME		MEAN ELAPSED TIME (MIN)	DISTANCE (MILES)		AVERAGE SPEED (MPH)		NUMBER OF STOPS (IDLES)		IDLE TIME (MIN)	
				MEAN	RANGE*		MEAN	RANGE**	MEAN	RANGE**	MEAN	RANGE**	MEAN	RANGE**
1A	WORK	1	NF	0721	0650 - 0752	21.4	8.3	0.1 - 12.0	23.3	10.0 - 35.0	9.3	0.0 - 13.0	1.7	0.0 - 3.0
1B	OR: WORK	1	NF	0715	0638 - 0742	8.2	3.1	0.1 - 9.0	22.7	10.0 - 35.0	4.0	0.0 - 8.0	1.6	0.0 - 2.0
		2	F			11.4	6.3	3.0 - 12.0	33.3	20.0 - 45.0	1.0	0.0 - 2.0	0.6	0.0 - 1.0
		3	NF			9.1	3.6	0.1 - 9.0	23.7	5.0 - 30.0	5.0	0.0 - 8.0	0.8	0.0 - 1.0
TRIPS 1A AND 1B OCCUR IN THE RATIO OF 2 TO 1 RESPECTIVELY														
2	S OR B	1	NF	1216	1139 - 1253	8.8	3.6	0.1 - 6.0	24.5	10.0 - 40.0	3.8	0.0 - 6.0	0.7	0.0 - 1.0
3	WORK	1	NF	1231	1200 - 1302	8.9	3.3	0.1 - 6.0	22.2	5.0 - 40.0	3.7	0.0 - 6.0	0.6	0.0 - 1.0
4A	HOME	1	NF	1719	1642 - 1753	21.1	8.3	0.1 - 12.0	23.6	15.0 - 35.0	6.9	0.0 - 12.0	1.0	0.0 - 2.0
4B	OR: HOME	1	NF	1709	1637 - 1741	9.9	3.6	0.1 - 9.0	21.9	10.0 - 30.0	4.9	0.0 - 8.0	0.9	0.0 - 1.0
		2	F			11.4	6.3	3.0 - 12.0	33.1	15.0 - 45.0	0.5	0.0 - 2.0	0.5	0.0 - 1.0
		3	NF			7.0	3.1	0.1 - 9.0	26.5	10.0 - 35.0	4.5	0.0 - 8.0	0.6	0.0 - 1.0
TRIPS 4A AND 4B OCCUR IN THE RATIO OF 2 TO 1 RESPECTIVELY														
						28.7	13.0				10.0		3.0	
									</					

* RANGE EQUALS MEAN PLUS OR MINUS ONE STANDARD DEVIATION

** RANGE CONTAINS AT LEAST 75% OF ALL CASES (SEE TEXT)

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TO TIME SLOT		0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359
FROM TIME SLOT	0000- 0559	2	3	0	0	2	0	0	0
	0600- 0859		9	3	6	5	21 W-H W-S	0	0
			0900- 1129	1	2	3	0	0	0
				1130- 1329	1	2	0	0	0
					1330- 1629	1	0	0	0
						1630- 1829	0	0	0
							1830- 2059	0	0
								2100- 2359	0

TRIP ONE TO TRIP TWO
TOTAL FIVE-TRIP WEEKDAYS: 61

LEGEND
H - Home S - Shopping
W - Work C - Church, School, etc.
B - Business R - Recreation

FIGURE 8
FIVE-TRIP WEEKDAY TRANSITION MATRIX

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TO TIME SLOT		0000-0559	0600-0859	0900-1129	1130-1329	1330-1629	1630-1829	1830-2059	2100-2359
FROM TIME SLOT	0000-0559	1	0	0	0	1	0	0	0
	0600-0859		2	1	3	2	3	0	1
	0900-1129			2	1	1	0	0	0
	1130-1329				5	3	0	1	0
	1330-1629					7	6	0	0
	1630-1829						12 S-H H-S	9 H-S	0
	1830-2059							0	0
	2100-2359								0

TRIP TWO TO TRIP THREE
TOTAL FIVE-TRIP WEEKDAYS: 61

LEGEND
H - Home S - Shopping
W - Work C - Church, School, etc.
B - Business R - Recreation

FIGURE 9
FIVE-TRIP WEEKDAY TRANSITION MATRIX

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TO TIME SLOT		0000-0559	0600-0859	0900-1129	1130-1329	1330-1629	1630-1829	1830-2059	2100-2359
FROM TIME SLOT	0000-0559	0	0	0	0	1	0	0	0
	0600-0859		0	0	0	0	2	0	0
			0900-1129	1	0	1	0	1	0
				1130-1329	5	0	4	0	0
					1330-1629	5	6	3	0
						1630-1829	7	12 H-S H-R	2
							1830-2059	8 S-S	2
								2100-2359	1

TRIP THREE TO TRIP FOUR
TOTAL FIVE-TRIP WEEKDAYS: 61

LEGEND

H - Home S - Shopping
W - Work C - Church, School, etc.
B - Business R - Recreation

FIGURE 10
FIVE-TRIP WEEKDAY TRANSITION MATRIX

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TO TIME SLOT		0000-0559	0600-0859	0900-1129	1130-1329	1330-1629	1630-1829	1830-2059	2100-2359
FROM TIME SLOT	0000-0559	0	0	0	0	0	0	0	0
	0600-0859		0	0	0	0	0	0	0
	0900-1129			0	0	0	1	0	0
	1130-1329				0	1	4	0	0
	1330-1629					1	3	1	2
	1630-1829						10 S-H	7	2
	1830-2059							16 S-H	8 R-H
	2100-2359								5

TRIP FOUR TO TRIP FIVE
TOTAL FIVE-TRIP WEEKDAYS: 61

LEGEND
H - Home S - Shopping
W - Work C - Church, School, etc.
B - Business R - Recreation

FIGURE 11

FIVE-TRIP WEEKDAY TRANSITION MATRIX

likelihood of detecting a typical pattern decreases. The matrices for the five-trip day require careful analysis of both time slot and purpose transitions to detect the pattern. In Figure 8, the modal transition from trip one to trip two is in cell 26 from work to home -- 11 out of 21 car-days. The matrix in Figure 9 showing trips two to three shows a modal transition in cell 66 with purpose pairs of home to shop, home to recreation, and home to school having high frequency -- but only six out of 12 car-days. Looking more closely at the adjacent cell, cell 67, we find that seven out of nine car-days also transition from home to these other purposes between trips two and three. In Figure 10, the modal transition is in cell 67, but the modal purpose transition is again from shopping to home. However, an examination of adjacent cells 66, 67, and 76 indicates that during these evening time slots, 14 out of a total of 27 cars transitioned between shopping, school and recreation locations. Then in Figure 11, the modal transition is in cell 77 where 13 out of 16 cars returned from shopping to home. In cell 78 all eight transitions were from recreation to home. From these indicators we derive the typical five-trip pattern shown in Table 7: trip one to work in time slot two; trip two to home in time slot six; trip three, a shopping, recreation or school trip, in time slot six; trip four, another similar trip, in time slot seven; and finally, trip five, a trip home, also in time slot seven. As with the four-trip (evening) pattern, the evening trips are divided between the trip segment string configurations N and NFN in the proportion three to one.

The Five-Trip Day Pattern was carried out by at least 14 cars. These represented 23% of all five-trip days and 3.1% of all car-weekdays.

TABLE 7
THE TYPICAL FIVE-TRIP DAY PATTERNS
(REPRESENTS 24% OF ALL FIVE-TRIP DAYS, 3.1% OF ALL COMPLETE CAR WEEKDAYS)

TRIP NUMBER	PURPOSE	SEGMENT NUMBER	ROUTE TYPE	START TIME		MEAN ELAPSED TIME (MIN)	DISTANCE (MILES)		AVERAGE SPEED (MPH)		NUMBER OF STOPS (HOURS)		TRIP TIME (MIN)	
				MEAN	RANGE*		MEAN	RANGE*	MEAN	RANGE*	MEAN	RANGE*	MEAN	RANGE*
1A	WORK OR:	1	NF	0721	0650 - 0752	21.4	8.3	0.1 - 12.0	23.3	10.0 - 35.0	9.3	0.0 - 13.0	1.7	0.0 - 3.0
1B	WORK	1	NF	0715	0638 - 0742	8.2	3.8	0.1 - 9.0	24.7	10.0 - 35.0	4.0	0.0 - 8.0	1.6	0.0 - 2.0
		2	F			11.4	6.8	3.0 - 12.0	33.3	20.0 - 45.0	1.0	0.0 - 2.0	0.6	0.0 - 1.0
		3	NF			9.1	3.6	0.1 - 9.0	23.7	5.0 - 30.0	5.0	0.0 - 8.0	0.8	0.0 - 1.0
TRIPS 1A AND 1B OCCUR IN THE RATIO OF 2 TO 1 RESPECTIVELY							13.0				10.0		3.0	
2A	HOME OR	1	NF	1719	1642 - 1753	21.1	8.3	0.1 - 12.0	23.6	15.0 - 35.0	6.9	0.0 - 12.0	1.0	0.0 - 2.0
2B	HOME	1	NF	1709	1637 - 1741	9.9	3.6	0.1 - 9.0	21.9	10.0 - 30.0	4.9	0.0 - 8.0	0.9	0.0 - 1.0
		2	F			11.4	6.3	3.0 - 12.0	33.1	15.0 - 45.0	0.5	0.0 - 2.0	0.5	0.0 - 1.0
		3	NF			7.0	3.1	0.1 - 9.0	26.5	10.0 - 35.0	4.5	0.0 - 8.0	0.6	0.0 - 1.0
TRIPS 2A AND 2B OCCUR IN THE RATIO OF 2 TO 1 RESPECTIVELY							13.0				9.9		2.1	
3A	S, C, R OR:	1	NF	1830	-	8.7	3.4	0.1 - 6.0	23.4	10.0 - 35.0	5.1	0.0 - 10.0	0.7	0.0 - 1.0
3B	S, C, R	1	NF	1830	-	4.8	2.1	0.1 - 3.0	26.3	10.0 - 40.0	3.7	0.0 - 6.0	1.1	0.0 - 1.0
		2	F			11.3	7.1	0.1 - 12.0	37.7	25.0 - 55.0	0.4	0.0 - 2.0	0.6	0.0 - 1.0
		3	NF			4.6	1.9	0.1 - 6.0	24.5	5.0 - 40.0	2.7	0.0 - 4.0	0.7	0.0 - 1.0
							11.1				6.8		2.4	
4A	S, C, R OR:	1	NF	1926	1846 - 2006	6.9	2.9	0.0 - 6.0	25.2	10.0 - 40.0	3.2	0.0 - 6.0	0.7	0.0 - 1.0
4B	S, C, R	1	NF	1914	1833 - 1955	4.6	1.9	0.1 - 3.0	24.7	10.0 - 35.0	2.6	0.0 - 4.0	0.9	0.0 - 1.0
		2	F			9.8	6.4	0.0 - 9.0	39.0	25.0 - 50.0	0.7	0.0 - 2.0	0.5	0.0 - 1.0
		3	NF			4.7	10.2	0.1 - 3.0	28.2	15.0 - 45.0	2.3	0.0 - 6.0	1.2	0.0 - 1.0
											5.6		2.6	
5A	HOME OR	1	NF	2051	-	10.6	4.3	0.0 - 6.0	24.3	10.0 - 35.0	4.2	0.0 - 8.0	0.9	0.0 - 1.0
5B	HOME	1	NF	2255	-	4.0	1.7	0.1 - 3.0	25.6	10.0 - 40.0	2.5	0.0 - 6.0	0.8	0.0 - 1.0
		2	F			8.4	4.9	0.1 - 9.0	35.1	15.0 - 50.0	0.3	0.0 - 2.0	0.6	0.0 - 1.0
		3	NF			5.3	2.7	0.1 - 6.0	30.5	10.0 - 55.0	2.2	0.0 - 4.0	0.9	0.0 - 1.0
IN THE TRIP PAIRS 3A-3B, 4A-4B, 5A-5B, THE A AND B TRIPS OCCUR IN THE RATIO 2 TO 1 RESPECTIVELY							9.3				5.0		2.3	

* RANGE EQUALS MEAN PLUS OR MINUS ONE STANDARD DEVIATION

GENERAL RESULTS

This section contains a discussion of additional results of the study including a description of the sample, an analysis of daily variations in the data, and an analysis of the individual trip and segment variables as they are affected by such factors as time of day, trip purpose, and type of route used.

The Houston Sample

During the Houston survey, SDC installed Tachographs in 99 automobiles. For various reasons, described more fully in the Appendix to this report, data from seven of these installations were totally unusable. The results of this study, then, are based on data from 92 automobiles driven in the Houston metropolitan area during the period January 20, 1969 to February 13, 1969. A total of 644 complete car-days are included in the sample. Nine of these car-days are incomplete because of the inability to match half-day data on them (see the paragraph below on the half-day bias). Therefore, daily pattern results are based on 635 complete car-days. Participants took 2974 trips during the survey, but 53 of them were judged invalid for the purpose of trip analysis because certain values associated with them (particularly average speed) were greater than one would realistically expect. Therefore, trip and segment analyses are based on data from 2923 trips. During these good trips, participants drove more than 22,000 miles. The average daily distance driven by each participant was 36 miles, during an average of 4.6 trips per day which required an average of one hour and seventeen minutes of travel time during each day.

Sample Biases

As discussed in Volume 0, Part II of this report, the method used in selecting survey participants biased the sample toward working members of the overall population. In view of this bias, SDC expected that work-related trips would constitute a major component of the resultant typical trip patterns described

in the previous section. There is no doubt in our minds that such work-related utilization represents a major, if not the major, component of the overall utilization pattern in the Houston urban area. The sample was made up of participants from all levels of the corporate structure within the participating firms, and the firms represented a reasonable cross-section, in terms of size, of all firms in the area. The results of the survey, therefore, represent a good cross-section of driving behavior within the industrial and commercial sector of the community.

A second bias which has been suggested is that the cars which participated in the survey, being primarily used for transportation to and from work, were not the types of cars people would use for extended trips on weekends or holidays. This would, according to those supporting this theory, explain the somewhat low incidence of long trips and the increased number of zero-trip days on weekends. This argument is bolstered by the fact that SDC chose to exclude station wagons, campers, and pickup trucks from the survey because of certain difficulties inherent in the installation of Tachographs in these vehicles. In the case of Houston this argument is bolstered by the decreased trip generation rate on weekends compared to weekdays, 4.3 trips per day on weekends versus 4.7 trips per day on weekdays. On the other hand, the trip generation rate among cars actually driven in Houston was 5.5 trips per day on weekends versus 4.9 trips per day on weekdays.

The logistics involved in installing Tachographs in the survey cars required a correction in the survey results to compensate for inconsistencies in the data. The instruments were installed during the morning and afternoon of the first survey day for each car. They were removed during the morning of the eighth day. As a result, the data collected during each car's week represented eight calendar days, but the first and eighth days each contained only about a half-day's worth of data. In order to remove this "half-day" bias which would certainly affect the daily pattern of automobile usage reflected in the results of the survey, data from the last half of the first day and from the

first half of the eighth day were combined during the data reduction process. In no case was there an overlap of trips on the two combined days that would cause the loss of a trip in the final results. In some cases, however, data from one of the two days was unusable for one reason or another (failure of the Tachograph, errors in the recorded data, etc.). In these cases, the daily records of the usable half-day were specially tagged and were removed from the analysis of daily patterns. Because their half-day nature would have no effect on the analysis of trip variables, these records were used in that portion of the study.

Data Collected

The Tachograph instrument provided data indicating the day of the survey, trip and trip segment¹ start times and complete times, trip and segment distance traveled, length of periods of idling time in excess of 40 seconds, number of momentary stops, and type of road (freeway, nonfreeway) traveled for each segment. Information contained in the log book kept by the driver indicated the date, the purpose of each trip, geographic zone within which each trip started, type of location from which each trip started, road conditions, driver sex and age, whether the car was parked indoors or out at the end of each trip, and the fuel gauge reading at the start of each day. To these data we added various identifying and categorizing variables during the data reduction process so that the final record on each trip contains at least 54 separate data items.

Daily Patterns

Two classifications of the survey data were made in the analysis. First, data were segregated into two groups by weekday and weekend day. The latter included only Saturday and Sunday. Second, the data were segregated into seven groups

¹ A trip segment is defined as that portion of a trip driven over a single type of road, either freeway or nonfreeway.

by day of the week. The latter was done at the request of CRC¹ to enable an examination of any daily variation that may occur.

The data base for the Houston survey contains 431 active car-weekdays and 143 active car-weekend days. To these sums must be added zero-trip days that occurred but are not contained in the data base: 20 car-weekdays and 41 car-weekend days. The resulting totals are 451 car-weekdays and 184 car-weekend days. Table 8 shows the daily breakdown of the sample into active and inactive car days.

TABLE 8
DAILY SAMPLE SIZE IN CAR-DAYS

DAY	NUMBER OF CAR-DAYS IN SAMPLE		
	ACTIVE	INACTIVE (O-TRIP)	TOTAL
MONDAY	88	1	89
TUESDAY	87	3	90
WEDNESDAY	85	5	90
THURSDAY	87	5	92
FRIDAY	84	6	90
SATURDAY	78	14	92
SUNDAY	65	27	92

During the survey period, participants drove 2923 valid trips. These were divided into 2123 weekday trips and 798 weekend trips. Tables 9 and 10 show the daily distribution by time slot of these trips as well as the weekday and weekend total distributions. Figure 12 presents a more detailed time distribution of weekday trip start times by fifteen-minute intervals. Figure 13 presents similar data for weekend trip start times.

¹ CRC-APRAC Project Groups CAPE-5 and CAPE-10.

TABLE 9
TIME DISTRIBUTION OF WEEKDAY
TRIPS BY DAY AND TIME SLOT

DAY	TIME SLOT								DAILY TOTAL
	0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359	
MONDAY	7	93	25	47	49	109	63	27	420
TUESDAY	6	93	36	49	60	101	65	17	427
WEDNESDAY	6	77	25	36	55	108	47	27	381
THURSDAY	7	84	37	53	60	101	78	30	450
FRIDAY	3	94	21	57	50	127	67	26	445
WEEKDAY TOTAL	29	441	144	242	274	546	320	127	2123

TABLE 10
TIME DISTRIBUTION OF WEEKEND
TRIPS BY DAY AND TIME SLOT

DAY	TIME SLOT						DAILY TOTAL
	0000- 0829	0830- 1059	1100- 1259	1300- 1759	1800- 2059	2100- 2359	
SATURDAY	43	82	86	194	55	22	482
SUNDAY	28	39	61	123	50	15	316
WEEKEND TOTAL	71	121	147	317	105	37	798

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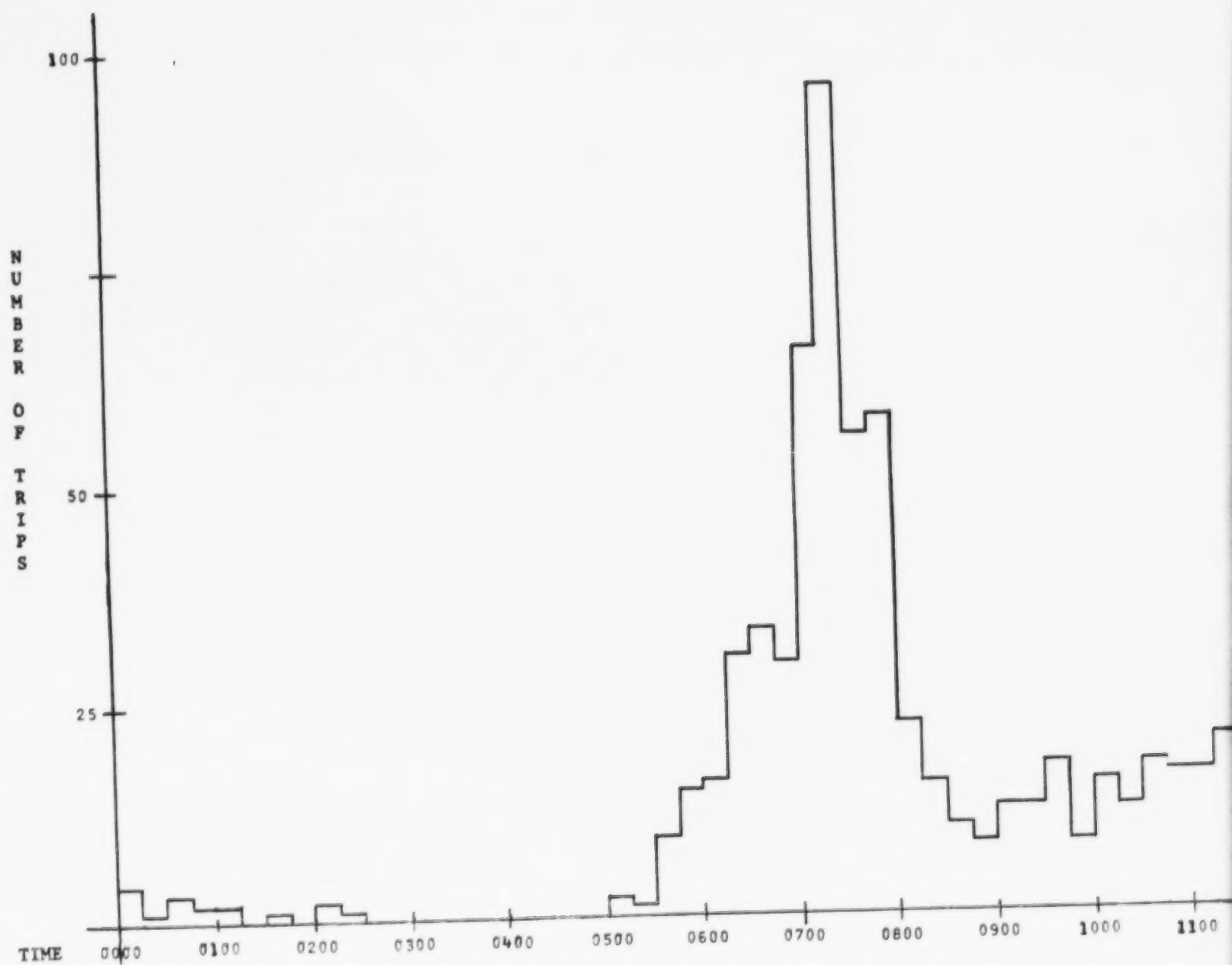
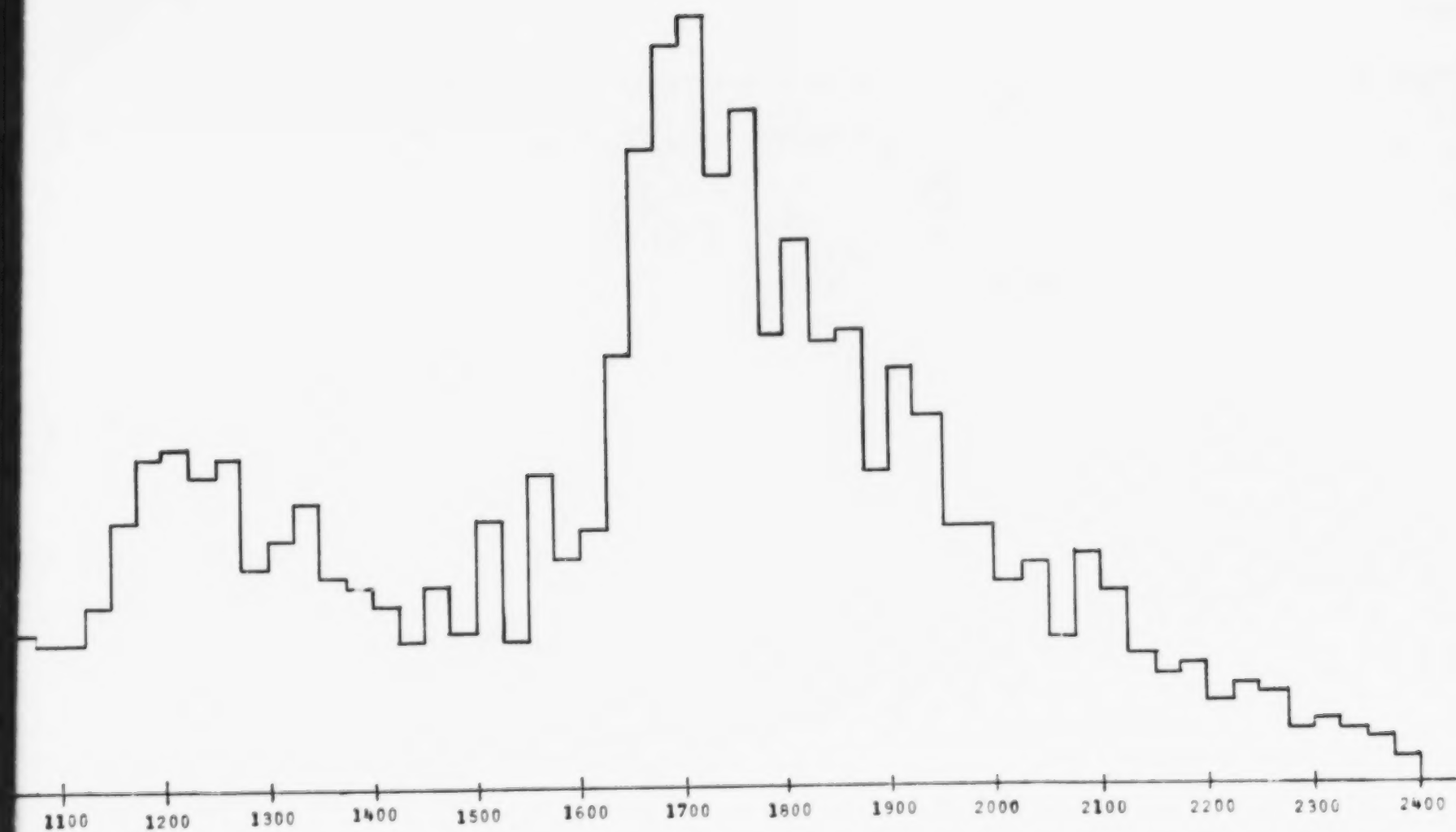


FIGURE 12
DISTRIBUTION OF WEEKDAY TRIP START TIMES

A



B

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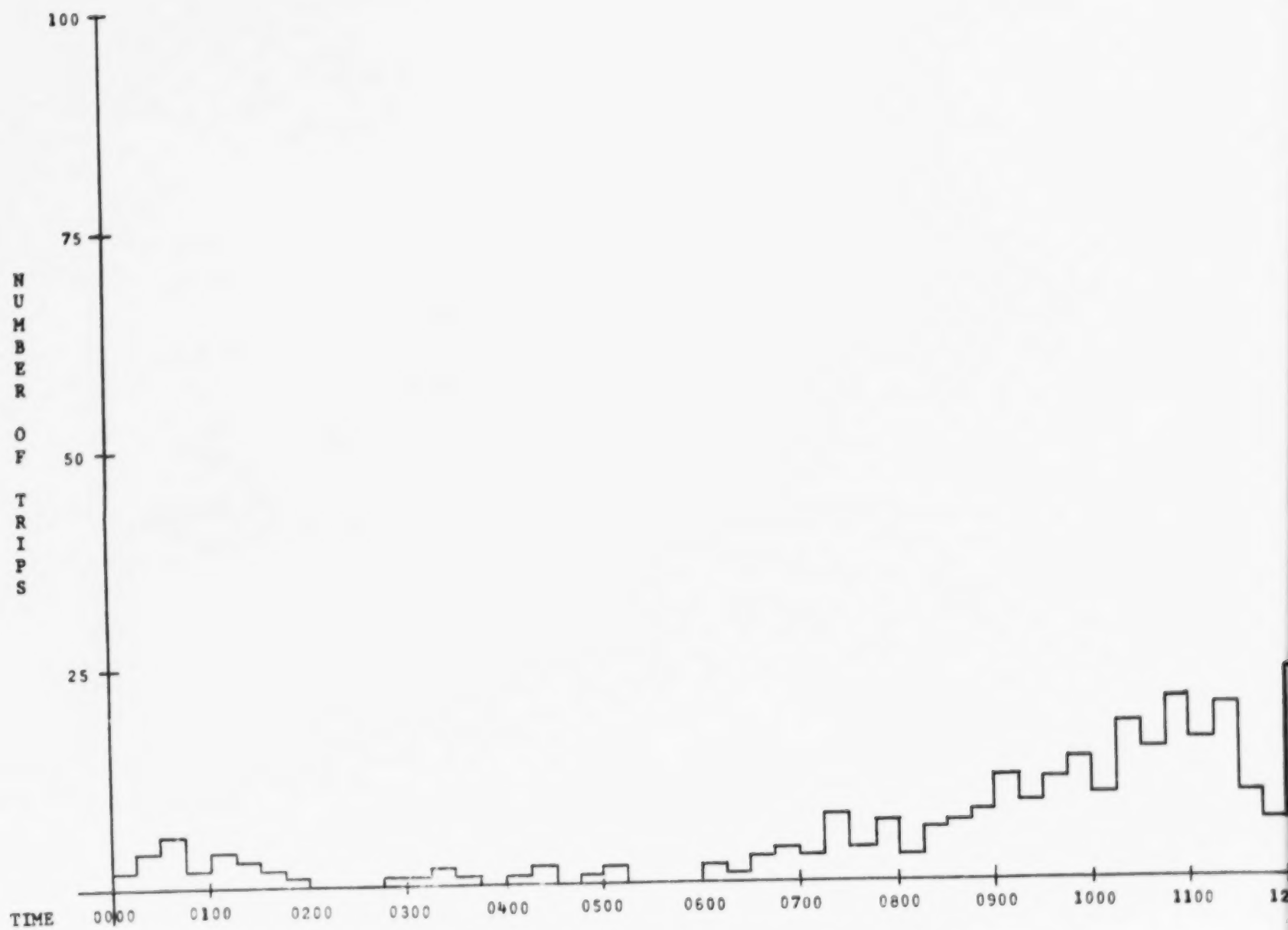
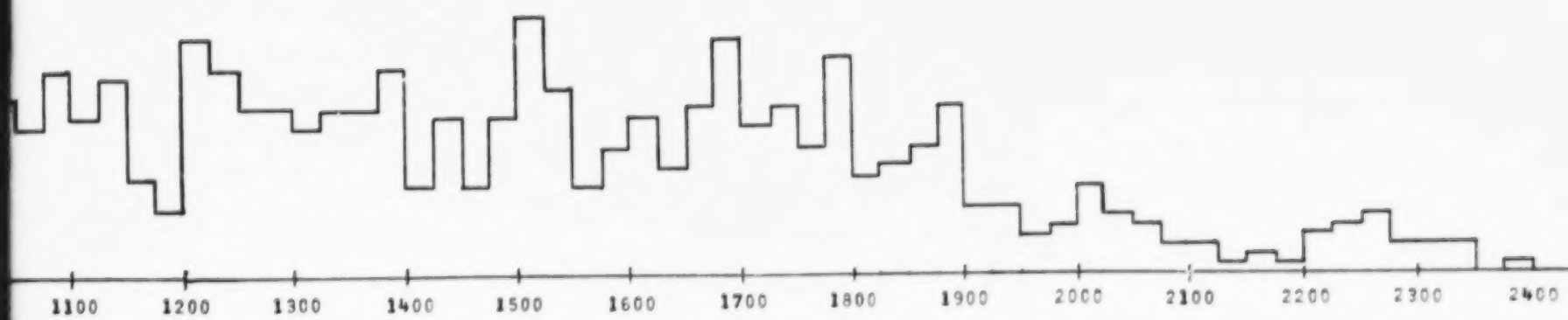


FIGURE 13
DISTRIBUTION OF WEEKEND TRIP START TIMES



B

Trip generation rates for weekday trips are 4.93 trips driven per day (i.e., including only those days on which trips were actually taken) and 4.71 trips per day for all days (i.e., including zero-trip days). On weekends, these rates are 5.59 and 4.34 trips per day respectively. The difference reflects the greater likelihood of a zero-trip day on a Saturday or Sunday.

An analytical tool that assisted greatly in determining trip pattern relationships is the trip-to-trip transition matrix. It is a tableau showing the incidence of various trip-related dependencies between successive trips. In order to examine weekday-weekend and daily variations, summary two-step, trip-to-trip transition matrices were assembled for all trips. Figures 14 and 15 are simplified versions of these matrices. The weekday matrix, of which only the upper right-hand triangle is shown, is divided into nine rows and eight columns. Rows two through nine and columns one through eight correspond to the eight weekday time slots. The first row is called the zero row and corresponds to any time slot on the previous day. A trip in the j^{th} time slot of any weekday that was preceded by a trip in the i^{th} time slot is tabulated in cell ij where i denotes the row and j denotes the column of the transition matrix. If a previous trip took place on the preceding day, the trip is tabulated in zero row in the column appropriate to its own time slot. In the original matrix, the purpose-to-purpose transition is also shown. We have simplified the matrix in Figure 14 by showing only the modal or typical purpose pattern(s) in cells that have high frequency counts. Figure 15 shows the matrix for weekend trips. This matrix is a seven-by-six matrix due to the reduced number of time slots on weekdays. The literal coded entries in certain cells indicate purpose-to-purpose transitions that clearly stand out as typifying the particular time slot transition.

A final analytical tool used to evaluate daily variation in trip patterns is a two-way contingency table showing the incidence of particular trip purpose and trip segment string combinations in each time slot. These tables were prepared for weekday, weekend, and daily breakdowns of the data. Chi-square

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TO TIME SLOT		0000-0559	0600-0859	0900-1129	1130-1329	1330-1629	1630-1829	1830-2059	2100-2359
FROM TIME SLOT	PREVIOUS DAY	23	358 W-H	25	13	6	4	2	0
	0000-0559	6	16	0	0	8	0	0	0
	0600-0859		65 B-W W-B S-W	58 W-B	62 W-S W-B	47	185 W-H	18	4
	0900-1129			63 B-B B-W	59 B-B	14	5	5	1
	1130-1329				110 S-W B-B	80 B-B	47 W-H	4	1
	1330-1629					125 B-B	100 W-H S-H	17	7
	1630-1829						207 S-H H-S	136 H-S H-R	20
	1830-2059							145 S-H	70 R-H
	2100-2359								26

WEEKDAY TOTAL TRIPS: 2142
(INCLUDES TRIPS CLASSIFIED AS "BAD" IN SUBSEQUENT ANALYSIS)

LEGEND
H - Home S - Shopping
W - Work C - Church, School, etc.
B - Business R - Recreation

FIGURE 14

TWO-STEP TRIP-TO-TRIP
TRANSITION MATRIX, ALL WEEKDAY TRIPS

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TO TIME SLOT		0000-0829	0830-1059	1100-1259	1300-1759	1800-2059	2100-2359
FROM TIME SLOT	PREVIOUS DAY	48	45	25	20	3	2
	0000-0829	23	23	9	10	3	1
	0830-1059		58	48	13	3	0
	1100-1259			67	59	9	2
	1300-1759				244 S-H S-S H-S	49	5
	1800-2059					41	17
	2100-2359						11

WEEKEND TOTAL TRIPS: 818
(INCLUDES TRIPS CLASSIFIED AS "BAD" IN SUBSEQUENT ANALYSIS)

LEGEND
H - Home S - Shopping
W - Work C - Church, School, etc.
B - Business R - Recreation

FIGURE 15
TWO-STEP TRIP-TO-TRIP
TRANSITION MATRIX, ALL WEEKEND TRIPS

tableaux were prepared for each of these tables to see which purpose stood out as typical for each time slot. In these tableaux, an "expected" frequency count is compiled for each cell by reallocating each column total over the cells in that column in proportion to the row totals. The assumption behind this computation is that row and column effects do not interact to affect the cell totals. In the case at hand, it is clear that these effects do interact (e.g., there is more likelihood of a go-to-work trip being taken in time slot two than in time slot eight). Because there is interaction, the differences between the actual cell counts and the "expected" cell counts obtained by computation indicate which purpose or trip segment string (row) is typical of the time slot. Tables 11 and 12 show the purpose-time slot contingency tables for weekday and weekend trips. "Expected" frequency counts for each cell are shown in italics below the actual frequency counts. Within the frequency table, the characteristic purpose(s) for each time slot is indicated by underlining the cell count we consider typical. The difficulty in selecting typical purposes is indicated in the weekend matrix where no trip purpose stands out both in terms of its absolute frequency (i.e., is a mode) and the difference between its actual and "expected" frequency. Therefore, the best measure of a typical purpose would be its absolute frequency.

An analysis of the individual weekday tables compared to the total weekday table in terms of percentage was carried out using the chi-square test. The purpose of the analysis was to detect any significant daily variation in the time slot distribution of trips or in the purpose distribution. The significance level of 0.95 was used. Results of the test showed that the seven weekdays constituted homogeneous samples with respect to both time slot and purpose distributions.

The time slot distribution of trip segment string is shown in Table 13 for weekday trips and in Table 14 for weekend trips. "Expected" frequencies are again shown in italics. The weekday figures indicate an interesting concentration of freeway utilization in the morning hours when compared to

TABLE 11
 ACTUAL AND "EXPECTED" FREQUENCIES OF TRIP PURPOSE
 BY TIME SLOT FOR WEEKDAY TRIPS
 CHARACTERISTIC TIME SLOT PURPOSES UNDERLINED

TIME SLOT PURPOSE	I 0000- 0559	II 0600- 0859	III 0900- 1129	IV 1130- 1329	V 1330- 1629	VI 1630- 1829	VII 1830- 2059	VIII 2100- 2359	TOTALS
GO HOME	12 9	17 <u>139</u>	15 45	24 <u>76</u>	72 86	311 <u>172</u>	134 <u>101</u>	84 <u>40</u>	669
GO TO WORK	7 7	351 <u>107</u>	31 35	63 59	42 66	9 <u>133</u>	5 78	7 31	515
BUSINESS	0 4	46 70	56 <u>23</u>	80 <u>38</u>	88 <u>43</u>	44 86	15 50	6 20	335
SHOP	7 5	21 82	31 27	64 <u>45</u>	56 51	114 <u>102</u>	92 <u>60</u>	10 24	395
SCHOOL	0 0	2 8	5 2	3 4	5 5	14 <u>10</u>	7 6	1 2	37
RECREATION	3 2	4 36	6 <u>12</u>	8 20	11 22	55 <u>45</u>	67 <u>26</u>	19 <u>10</u>	173
TOTALS	29	441	144	242	274	547	320	127	2124

ACTUAL FREQUENCY
 "EXPECTED" FREQUENCY (IN ITALICS)

TABLE 12
 ACTUAL AND "EXPECTED" FREQUENCIES OF TRIP PURPOSE
 BY TIME SLOT FOR WEEKEND TRIPS
 CHARACTERISTIC TIME SLOT PURPOSES UNDERLINED

TIME SLOT PURPOSE	I 0000- 0829	II 0830- 1059	III 1100- 1259	IV 1300- 1759	V 1800- 2059	IV 2100- 2359	TOTALS
GO HOME	30 25	27 43	49 52	115 113	43 37	21 13	285
GO TO WORK	14 4	8 6	4 7	8 16	4 5	2 2	40
BUSINESS	4 4	15 7	8 8	17 18	1 6	0 2	45
SHOPPING	9 21	42 36	56 43	107 93	16 31	5 11	235
SCHOOL	1 2	16 4	2 5	5 10	2 3	0 1	26
RECREATION	13 15	13 25	28 31	65 67	39 22	9 8	167
TOTALS	71	121	147	317	105	37	798

ACTUAL FREQUENCY
 "EXPECTED" FREQUENCY

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TABLE 13

ACTUAL AND "EXPECTED" FREQUENCIES OF TRIP
SEGMENT STRING BY TIME SLOT FOR WEEKDAYS

TRIP SEGMENT STRING	TIME SLOT								TOTALS
	0000- 0559	0600- 0859	0800- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359	
N	20 20	274 308	102 100	184 169	185 191	404 282	230 223	83 89	1482
NFN	4 7	131 106	32 34	40 58	67 66	122 131	75 77	38 30	509
NFNFN	3 2	30 22	8 7	14 12	18 14	17 28	13 16	4 6	107
OTHER	2 0	6 5	2 2	4 3	4 3	4 7	2 4	2 2	26
TOTALS	29	441	144	242	274	547	320	127	2124

ACTUAL FREQUENCY

"EXPECTED" FREQUENCY

N = NONFREEWAY SEGMENT

F = FREEWAY SEGMENT

TABLE 14

ACTUAL AND "EXPECTED" FREQUENCIES OF TRIP
SEGMENT STRING BY TIME SLOT FOR WEEKENDS

TRIP SEGMENT STRING	TIME SLOT						TOTALS
	0000- 0829	0830- 1059	1100- 1259	1300- 1359	1800- 2059	2100- 2359	
N	44 55	97 94	123 114	250 246	80 82	26 29	620
NFN	17 12	18 20	19 25	48 53	23 18	9 6	134
NFNFN	8 3	5 6	5 7	17 15	2 5	1 2	38
OTHER	2 0	1 1	0 1	2 2	0 1	1 0	6
TOTALS	71	121	147	317	105	37	798

ACTUAL FREQUENCY

"EXPECTED" FREQUENCY

N = NONFREEWAY SEGMENT

F = FREEWAY SEGMENT

the "expectations." The disparity between actual and "expected" frequencies does not recur to the same extent during the evening rush hour even though there are similarly large numbers of trips that use freeways. No doubt this is indicative of the high likelihood that a trip to or from work will use freeways for part of its completion. During the morning hours, especially in time slot two, trips to work constitute such a major portion of all traffic that anything characteristic of them will dominate the statistics of the period. On weekends the use of freeways is diminished both in frequency and in comparison between actual and "expected" frequency in all but the first time slot.

Trip Descriptors

The discussion of general results so far has dealt with the incidence of variables that can only be counted. These variables essentially define cases under which we wish to examine the behavior of such trip-descriptive variables as distance, elapsed time, velocity, number of stops with engine on and off, and idling time. The present section is devoted to a detailed examination of these variables.

Trip and Segment Distance

The average distance per trip driven during the survey was 7.79 miles. This number is deceptive, however. The distribution of trip distances understandably shows a wide range as is indicated in Figure 16, Distribution of Weekday Trip Distance, and in Figure 17, Distribution of Weekend Trip Distance. Of more particular interest is the time distribution of distance with respect to trip segment string. Tables 15 and 16 show the time slot distribution of number of trips by trip segment string for weekday and weekend respectively along with the average trip distance for each type of trip during the time slot. Tables 17 and 18 show the distribution of segment distance by time slot for nonfreeway and freeway segments associated with freeway trips on weekdays and weekend days.

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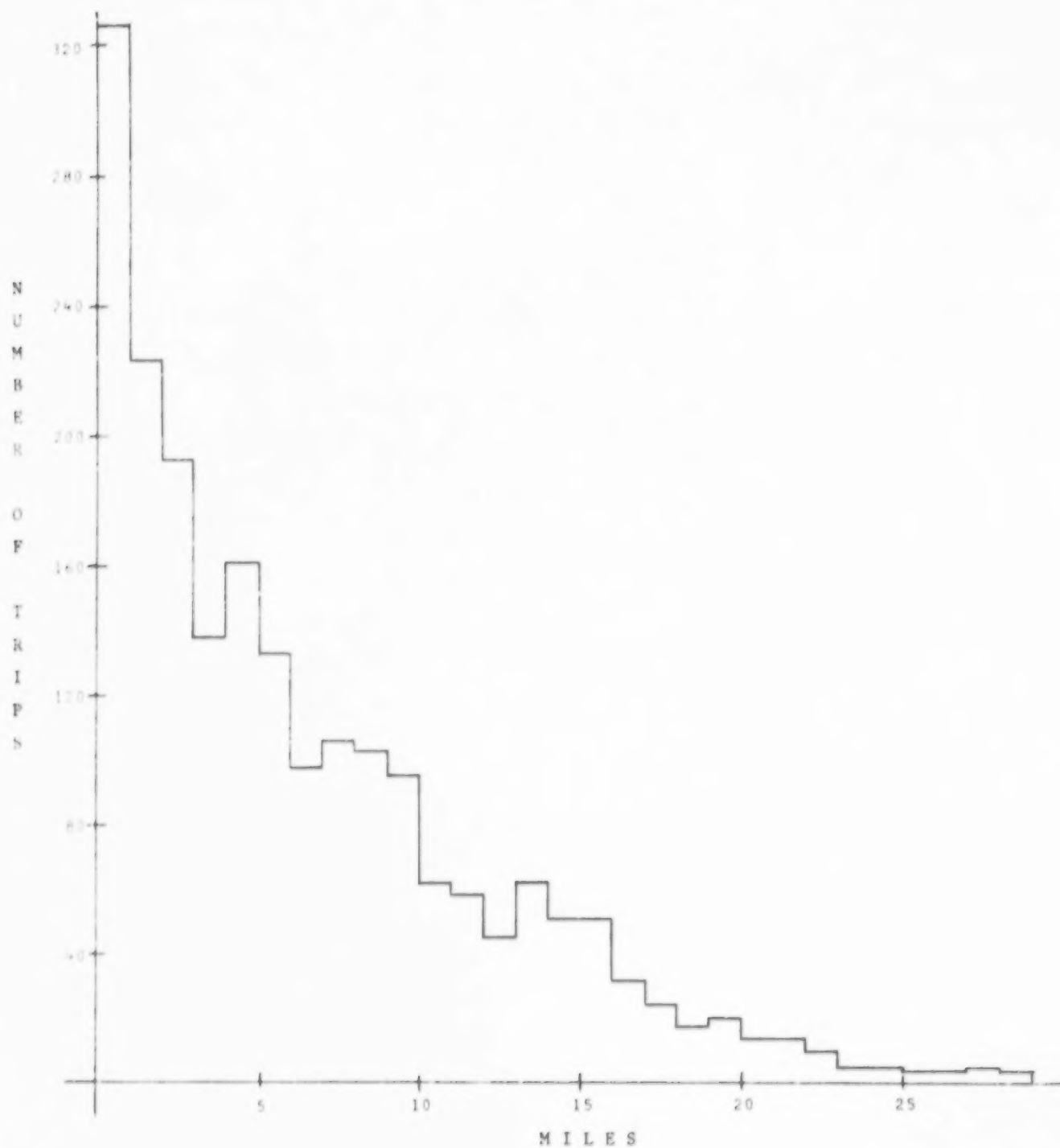


FIGURE 16
DISTRIBUTION OF TRIP DISTANCE, WEEKDAY TRIPS

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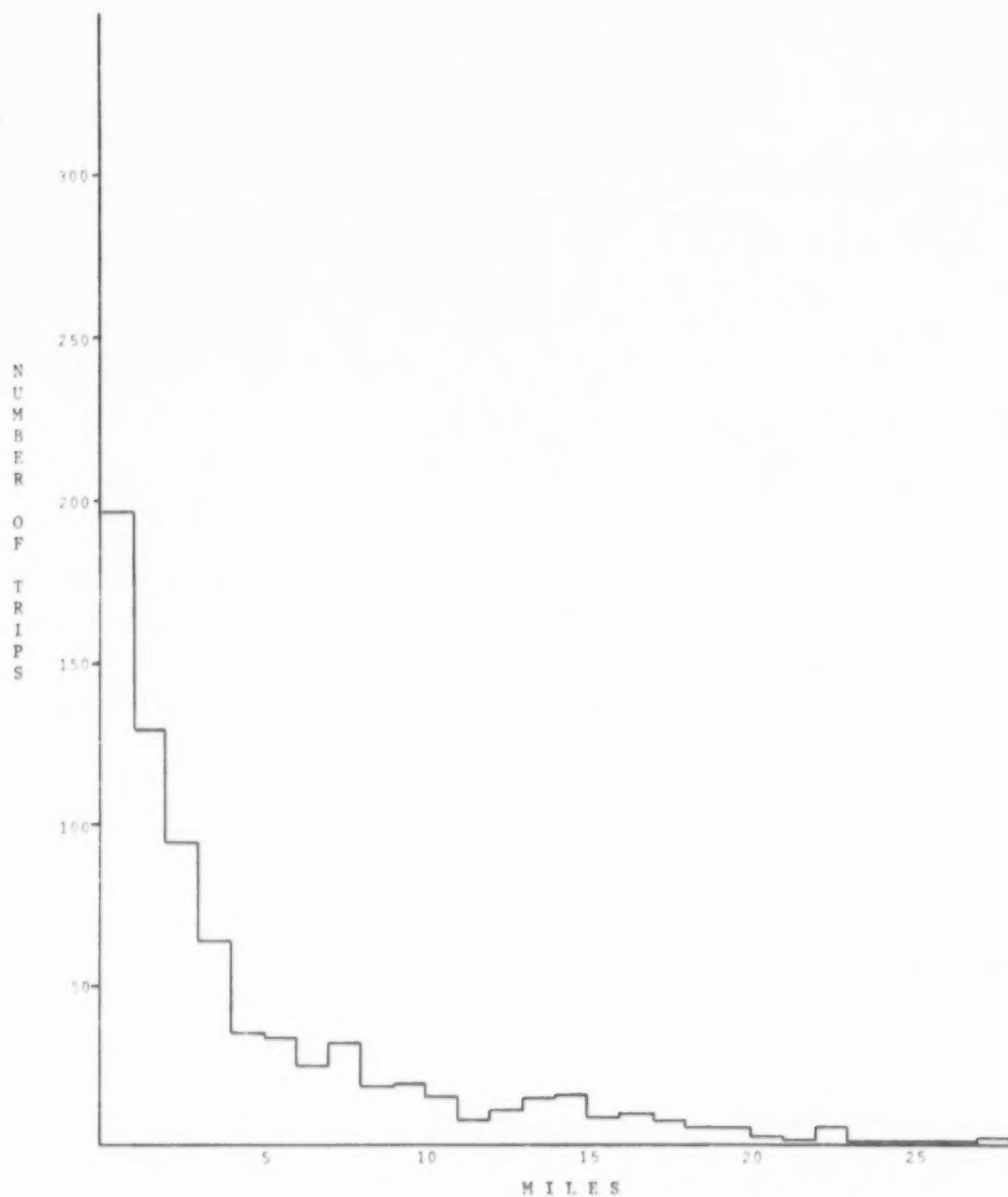


FIGURE 17
DISTRIBUTION OF TRIP DISTANCE, WEEKEND TRIPS

TABLE 15

DISTRIBUTION OF WEEKDAY TRIPS IN HOUSTON SURVEY BY TRIP
SEGMENT STRING SHOWING AVERAGE DISTANCE PER TRIP FOR EACH CASE

TRIP SEGMENT STRING	TIME SLOT								TOTAL
	0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359	
N: NUMBER OF CASES MEAN DISTANCE (MI.)	20 4.4	274 7.2	102 3.7	184 3.5	185 4.8	404 5.3	230 3.7	83 5.2	1482 5.0
NFN: NUMBER OF CASES MEAN DISTANCE	4 10.8	131 13.3	32 13.0	40 11.7	67 18.0	122 11.1	75 10.0	38 9.4	509 12.5
NFNFN: NUMBER OF CASES MEAN DISTANCE	3 17.5	30 19.3	8 25.4	14 18.2	18 26.6	17 31.0	13 14.9	4 33.0	107 22.6
OTHER: NUMBER OF CASES MEAN DISTANCE	2 5.0	6 44.0	2 9.5	4 13.0	4 61.2	4 80.2	2 51.5	2 57.0	26 43.4
TOTAL: NUMBER OF CASES MEAN DISTANCE	29 6.6	441 10.3	144 7.1	242 5.9	274 10.3	547 8.0	320 5.9	127 8.2	2124 8.2

TABLE 16

DISTRIBUTION OF WEEKEND TRIPS IN HOUSTON SURVEY BY TRIP
SEGMENT STRING SHOWING AVERAGE DISTANCE PER TRIP FOR EACH CASE

TRIP SEGMENT STRING	TIME SLOT						TOTAL
	0000- 0829	0830- 1059	1100- 1259	1300- 1759	1800- 2059	2100- 2359	
N: NUMBER OF CASES MEAN DISTANCE (MI.)	44 4.7	97 4.2	123 3.8	250 3.0	80 3.6	26 4.2	620 3.6
NFN: NUMBER OF CASES MEAN DISTANCE	17 12.2	18 22.2	19 12.3	48 20.0	23 8.6	9 8.5	134 15.5
NFNFN: NUMBER OF CASES MEAN DISTANCE	8 20.0	5 38.2	5 28.1	17 26.9	2 35.0	1 16.5	38 27.2
OTHER: NUMBER OF CASES MEAN DISTANCE	2 30.5	1 0.5	0 0.0	2 16.0	0 0.0	1 18.5	6 18.7
TOTAL: NUMBER OF CASES MEAN DISTANCE	71 8.9	121 8.3	147 5.7	317 7.0	105 5.3	37 6.0	798 6.8

TABLE 17
AVERAGE DISTANCE FOR SEGMENTS OF WEEKDAY
FREEWAY TRIPS BY TIME SLOT AND ROUTE TYPE

ROUTE TYPE	TIME SLOT								TOTAL
	0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359	
NONFREEWAY ¹									
NUMBER OF CASES	24	369	94	135	203	314	199	88	1426
AVERAGE DISTANCE	3.2	3.2	2.9	2.5	2.7	2.7	2.2	2.6	2.7
FREEWAY									
NUMBER OF CASES	12	211	55	77	126	172	109	48	810
AVERAGE DISTANCE	4.9	6.5	9.9	6.7	12.1	7.6	6.2	6.9	7.8
TOTAL									
NUMBER OF CASES	36	580	149	212	329	486	308	136	2236
AVERAGE DISTANCE	3.7	4.4	5.5	4.0	6.3	4.4	3.6	4.2	4.6

¹ EXCLUDES NONFREEWAY SEGMENTS IN NONFREEWAY TRIPS

(I.E., TRIPS WITH "N" TRIP SEGMENT SEQUENCE)

TABLE 18
AVERAGE DISTANCE FOR SEGMENTS OF WEEKEND FREEWAY TRIPS
IN HOUSTON SUPPLY BY TIME SLOT AND ROUTE TYPE

ROUTE TYPE	TIME SLOT						TOTAL
	0000- 0829	0830- 1059	1100- 1259	1300- 1759	1800- 2059	2100- 2359	
NONFREEWAY ¹							
NUMBER OF CASES	65	53	50	153	51	25	397
AVERAGE DISTANCE	2.6	3.2	2.8	3.9	1.7	1.8	3.1
FREEWAY							
NUMBER OF CASES	39	31	27	88	29	13	227
AVERAGE DISTANCE	6.3	11.5	8.2	9.2	8.2	4.7	8.5
TOTAL							
NUMBER OF CASES	104	84	77	241	80	38	624
AVERAGE DISTANCE	4.0	6.3	4.7	5.8	4.0	2.8	5.0

¹ EXCLUDES NONFREEWAY SEGMENTS IN NONFREEWAY TRIPS
(I.E., TRIPS WITH "N" TRIP SEGMENT SEQUENCE)

The data in Figures 16 and 17 are arbitrarily cut off above 28 miles. Nevertheless, these figures account for 96.9% of all weekday trips and 96.1% of all weekend trips.

Trip and Segment Velocity

The distribution of trip velocity, as shown in Figure 18 for weekdays and in Figure 19 for weekends, is unimodal in both cases (i.e., single-peaked). The weekend distribution is, however, slightly more spread as indicated by its larger standard deviation, 12.5 versus 10.0 for weekday trips. The means are almost identical: 25.2 miles per hour for weekday trips and 25.7 miles per hour for weekend trips. Again, the time and trip segment string distribution points out greater differences. Tables 19 and 20 are analogous to the previous tabular presentation on trip distance. One notices increased average velocities on all freeway-associated trips as compared to the non-freeway trips. But the degree of increase varies with time slot and in time slots two and six, the morning and evening rush hours, the difference decreased markedly.

Tables 21 and 22 provide average velocity information on freeway and freeway segments associated with freeway trips by time slot for weekdays and weekends.

Trip and Segment Elapsed Time

The distributions of elapsed time for weekday and weekend trips are shown in Figures 20 and 21 respectively. The mean for weekday trips is 17.9 minutes, for weekend trips it is 14.0 minutes. The weekday distribution indicates that 90% of all trips on these days are completed within 37 minutes. On weekends, this figure drops to 31 minutes.

Tables 23 and 24 show the mean elapsed time by time slot and trip segment string. The dependency of elapsed time on the complexity of the trip segment structure stands out clearly. Tables 25 and 26 present mean segment elapsed times for trips involving the use of freeways on weekdays and weekend days. The large number of short trip times is obviously related to the similar prevalence of short trip distances discussed previously.

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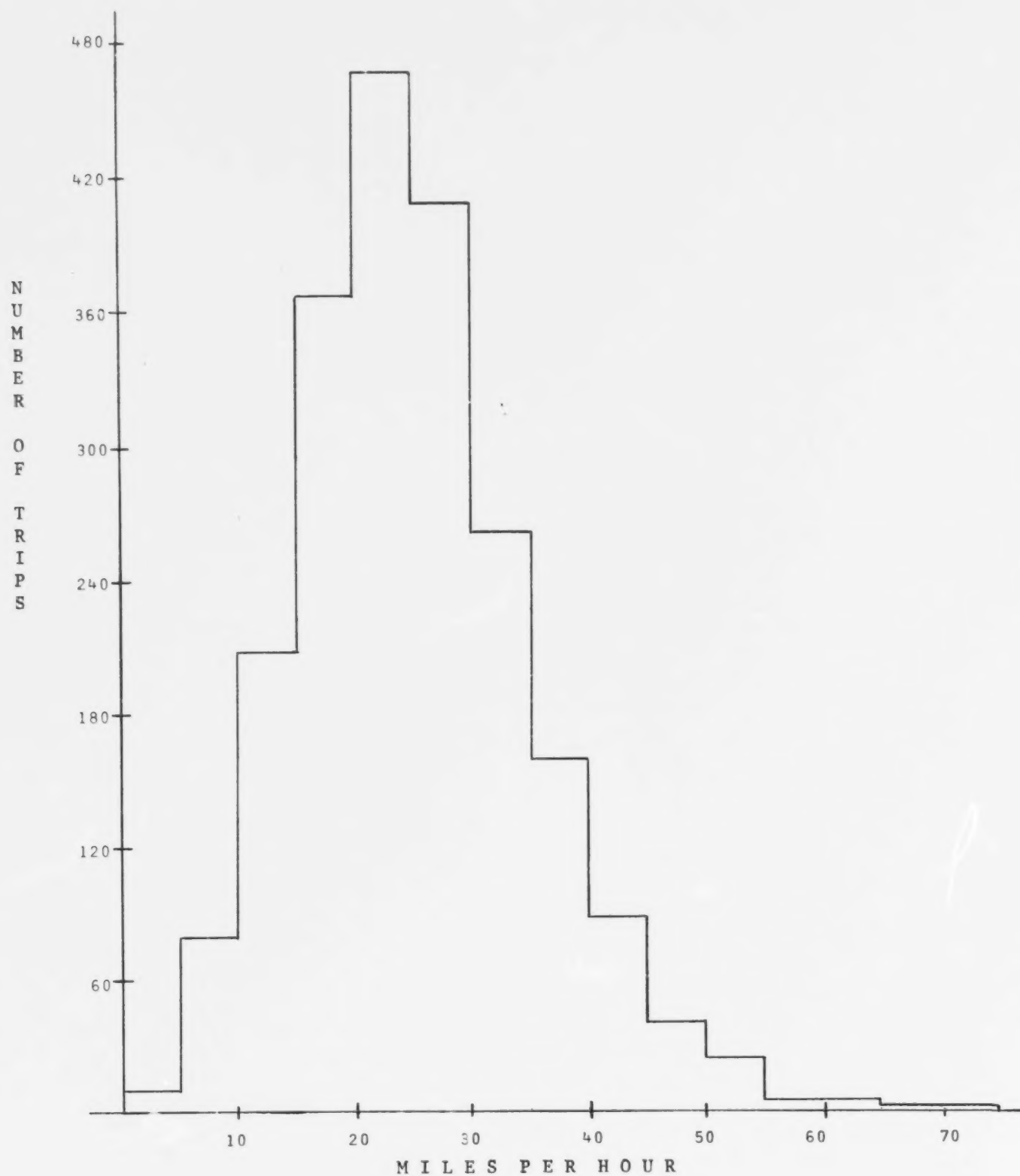


FIGURE 18
DISTRIBUTION OF AVERAGE SPEED, WEEKDAY TRIPS

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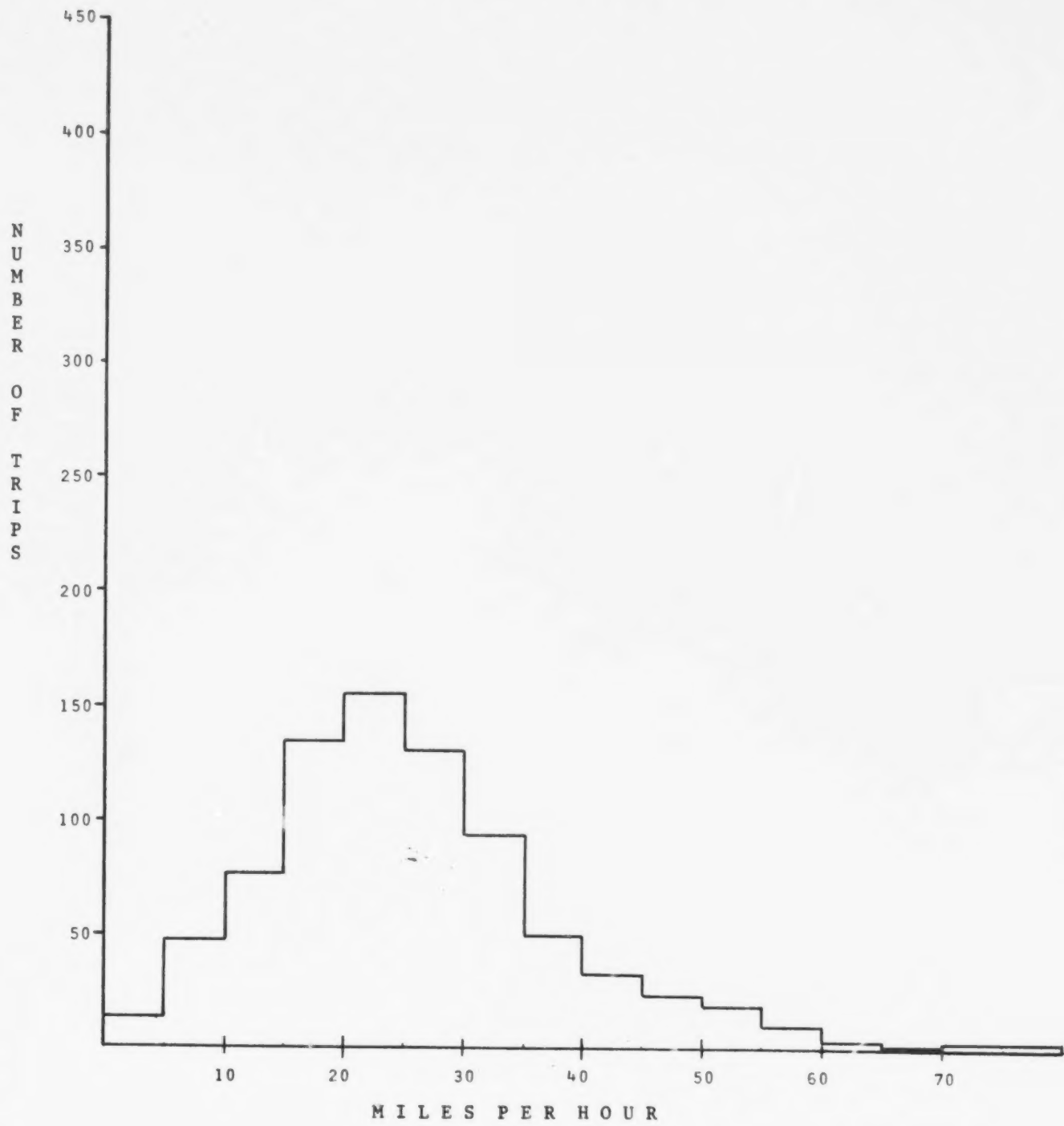


FIGURE 19
DISTRIBUTION OF AVERAGE SPEED, WEEKEND TRIPS

TABLE 19

DISTRIBUTION OF WEEKDAY TRIPS IN HOUSTON SURVEY BY TRIP
SEGMENT STRING SHOWING AVERAGE SPEED IN MILES PER HOUR PER TRIP FOR EACH CASE

TRIP SEGMENT STRING	TIME SLOT								TOTAL
	0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359	
N: NUMBER OF CASES AVERAGE SPEED (MPH)	20 23.8	274 22.3	102 22.6	184 24.0	185 20.1	404 23.4	230 25.0	83 24.0	1482 23.1
NFN: NUMBER OF CASES AVERAGE SPEED	4 35.0	131 26.7	32 31.2	40 31.8	67 32.4	122 29.1	75 31.3	38 28.8	509 29.6
NFNFN: NUMBER OF CASES AVERAGE SPEED	3 32.5	30 28.7	8 36.2	14 34.3	18 36.1	17 37.8	13 32.5	4 31.2	107 32.5
OTHER: NUMBER OF CASES AVERAGE SPEED	2 27.5	6 27.5	2 37.5	4 22.5	4 37.5	4 41.2	2 27.5	2 42.5	26 32.3
TOTAL: NUMBER OF CASES AVERAGE SPEED	29 26.5	441 ¹ 23.5	144 25.4	242 25.8	274 24.4	547 25.1	320 26.8	127 26.0	2124 25.1

TABLE 20

DISTRIBUTION OF WEEKEND TRIPS IN HOUSTON SURVEY BY TRIP
SEGMENT STRING SHOWING AVERAGE SPEED IN MILES PER HOUR PER TRIP FOR EACH CASE

TRIP SEGMENT STRING	TIME SLOT						TOTAL
	0000- 0829	0830- 1059	1100- 1259	1330- 1759	1800- 2059	2100- 2359	
N: NUMBER OF CASES AVERAGE SPEED (MPH)	44 21.6	97 22.6	123 24.5	250 23.7	80 26.4	26 21.0	620 23.8
NFN: NUMBER OF CASES AVERAGE SPEED	17 31.9	18 36.4	19 33.3	48 33.4	23 29.9	9 27.5	134 32.6
NFNFN: NUMBER OF CASES AVERAGE SPEED	8 32.5	5 36.5	5 35.5	17 30.4	2 40.0	1 32.5	38 32.9
OTHER: NUMBER OF CASES AVERAGE SPEED	2 35.0	1 12.5	0 0.0	2 30.0	0 0.0	1 27.5	6 28.3
TOTAL: NUMBER OF CASES AVERAGE SPEED	71 25.7	121 25.1	147 26.0	317 25.6	105 27.4	37 32.0	798 25.7

TABLE 21
AVERAGE SPEED FOR SEGMENTS OF WEEKDAY FREEWAY
TRIPS BY TIME SLOT AND ROUTE TYPE

ROUTE TYPE	TIME SLOT								TOTAL
	0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359	
NONFREEWAY ¹									
NUMBER OF CASES	24	369	94	135	203	314	199	88	1426
AVERAGE SPEED	32.1	23.6	28.0	26.5	28.3	25.8	27.6	23.3	26.0
FREEWAY									
NUMBER OF CASES	12	211	55	77	126	172	109	48	810
AVERAGE SPEED	34.2	34.3	39.9	36.7	38.8	35.8	37.7	36.0	36.5
TOTAL									
NUMBER OF CASES	36	580	149	212	329	486	308	136	2236
AVERAGE SPEED	32.8	27.5	32.4	30.2	32.3	29.4	31.2	27.8	29.8

¹ EXCLUDES NONFREEWAY SEGMENTS IN NONFREEWAY TRIPS
(I.E., TRIP WITH N-TRIP SEGMENT SEQUENCE)

TABLE 22
AVERAGE SPEEDS FOR SEGMENTS OF WEEKEND FREEWAY
TRIPS IN HOUSTON SURVEY BY TIME SLOT AND ROUTE TYPE

ROUTE TYPE	TIME SLOT						TOTAL
	0000- 0829	0830- 1059	1100- 1259	1300- 1759	1800- 2059	2100- 2359	
NONFREEWAY ¹							
NUMBER OF CASES	65	53	50	153	51	24	397
AVERAGE SPEED	25.2	30.0	24.9	27.2	24.1	22.5	26.2
FREEWAY							
NUMBER OF CASES	39	31	27	88	29	13	227
AVERAGE SPEED	39.8	37.8	43.8	37.8	38.7	32.5	38.7
TOTAL							
NUMBER OF CASES	104	84	77	241	80	38	624
AVERAGE SPEED	30.7	32.9	31.5	31.1	29.4	25.9	30.8

¹ EXCLUDES NONFREEWAY SEGMENTS IN NONFREEWAY TRIPS
(I.E., TRIPS WITH "N" TRIP SEGMENT SEQUENCE)

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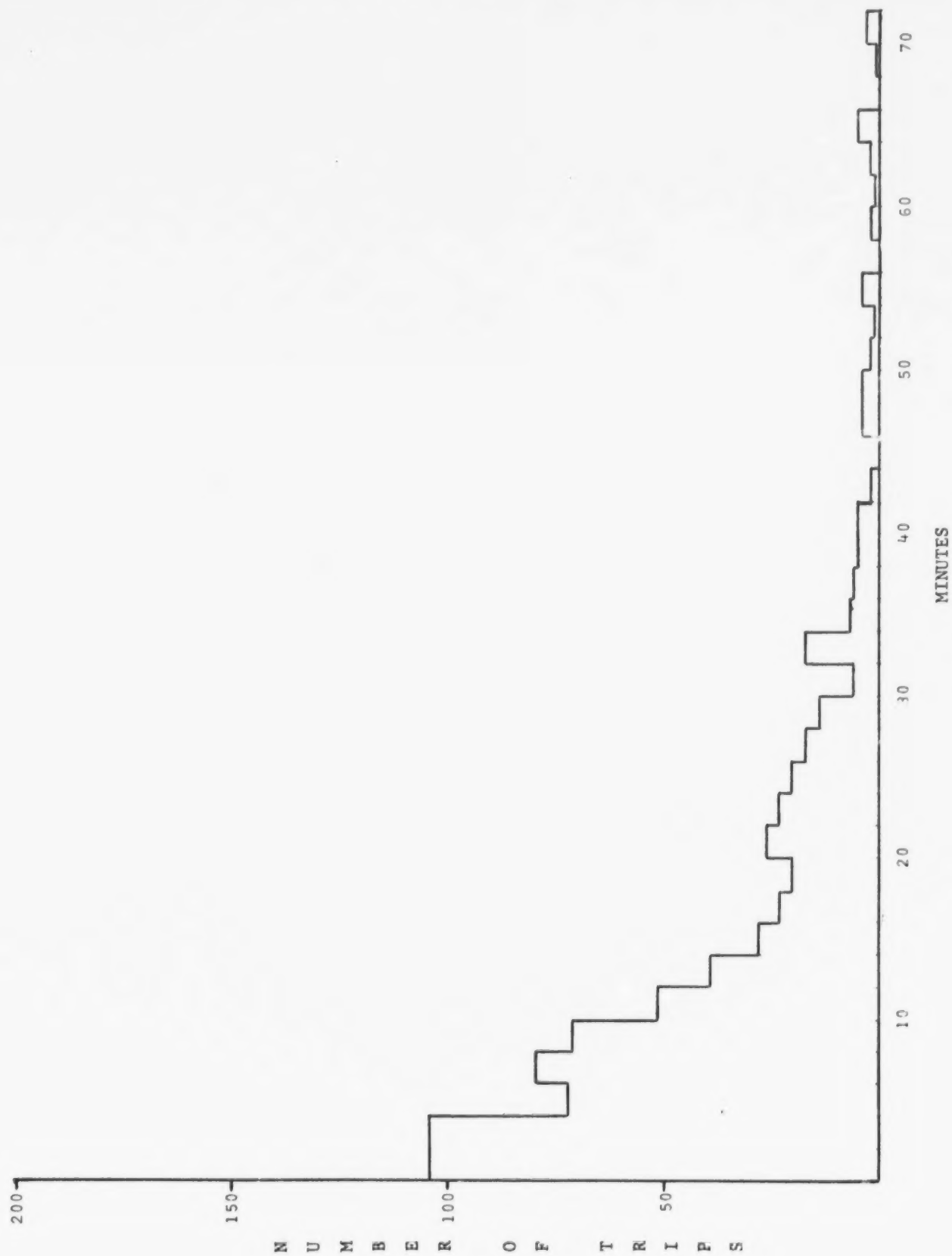


FIGURE 20
DISTRIBUTION OF TRIP TIME, WEEKDAY TRIPS

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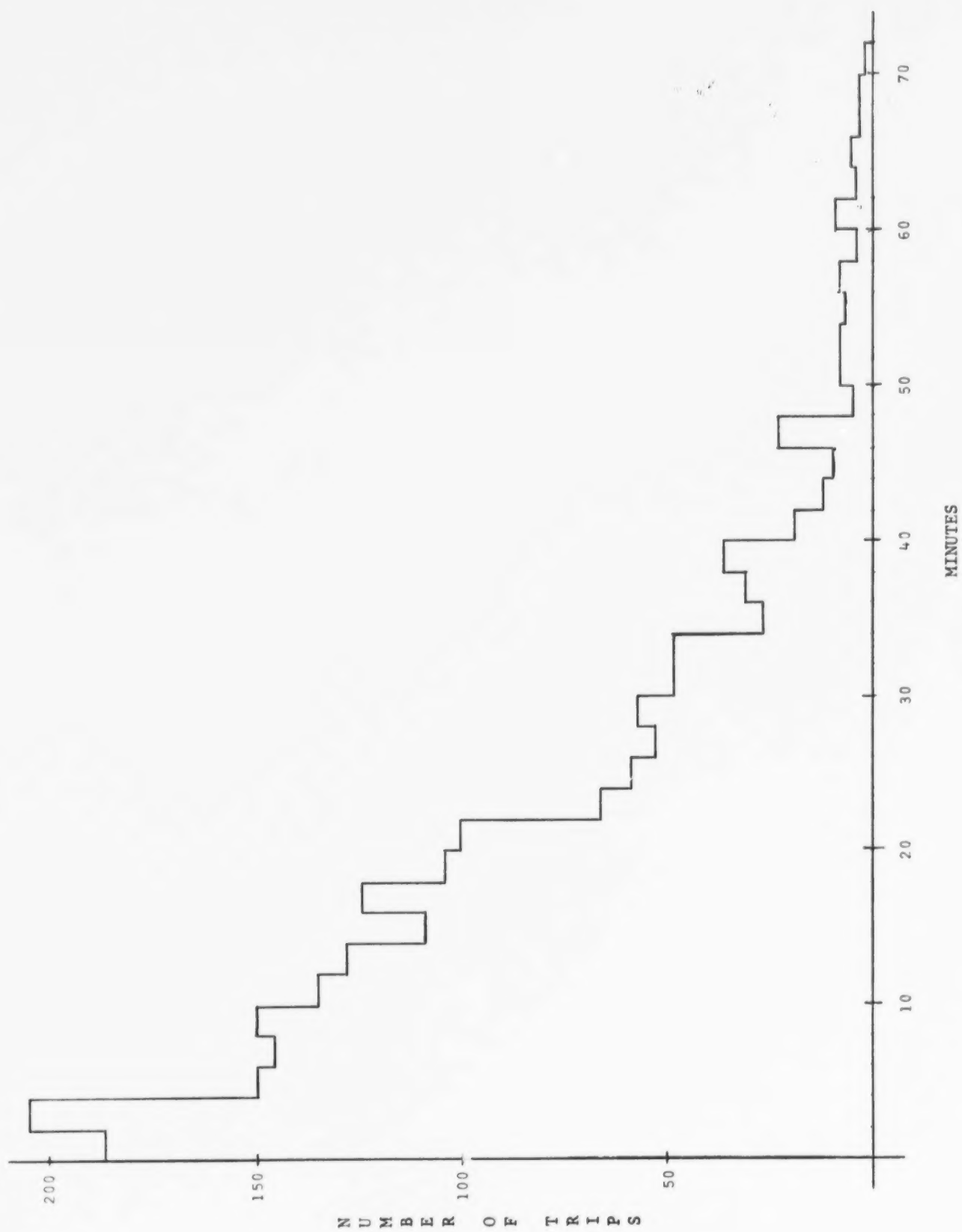


FIGURE 21
DISTRIBUTION OF TRIP TIME, WEEKEND TRIPS

TABLE 23

DISTRIBUTION OF WEEKDAY TRIPS IN THE HOUSTON SURVEY BY TRIP SEGMENT
STRING SHOWING AVERAGE TRIP ELAPSED TIME IN MINUTES PER TRIP FOR EACH CASE

TRIP SEGMENT STRING	TIME SLOT								TOTAL
	0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359	
N: NUMBER OF CASES ELAPSED TIME (MIN)	20 10.0	274 19.6	102 9.5	184 8.6	185 12.0	404 13.9	230 9.1	83 12.2	1482 12.9
NFN: NUMBER OF CASES ELAPSED TIME	4 17.5	131 31.7	32 24.2	40 19.9	67 29.1	122 24.0	75 19.4	38 19.2	509 25.3
NFNFN: NUMBER OF CASES ELAPSED TIME	3 32.3	30 40.7	8 36.2	14 32.7	18 43.2	17 51.4	13 29.9	4 64.0	107 40.8
OTHER: NUMBER OF CASES ELAPSED TIME	2 10.0	6 73.7	2 17.0	4 30.0	4 108.0	4 96.0	2 72.0	2 85.0	26 67.2
TOTAL: NUMBER OF CASES ELAPSED TIME	29 13.3	441 26.5	144 14.4	242 12.3	274 19.7	547 17.9	320 12.7	127 17.1	2124 17.9

TABLE 24

DISTRIBUTION OF WEEKEND TRIPS IN THE HOUSTON SURVEY BY TRIP SEGMENT
STRING SHOWING AVERAGE TRIP ELAPSED TIME IN MINUTES PER TRIP FOR EACH CASE

TRIP SEGMENT STRING	TIME SLOT						TOTAL
	0000- 0829	0830- 1059	1100- 1259	1300- 1759	1800- 2059	2100- 2359	
N: NUMBER OF CASES ELAPSED TIME (MIN)	44 12.4	97 10.6	123 10.0	250 8.1	80 8.2	26 13.5	620 9.4
NFN: NUMBER OF CASES ELAPSED TIME	17 21.4	18 24.8	19 22.3	48 32.4	23 18.1	9 17.4	134 25.1
NFNFN: NUMBER OF CASES ELAPSED TIME	8 37.8	5 47.0	5 46.2	17 47.6	2 29.0	1 33.0	38 46.3
OTHER: NUMBER OF CASES ELAPSED TIME	2 51.0	1 3.0	0 0.0	2 33.0	0 0.0	1 37.0	6 20.7
TOTAL: NUMBER OF CASES ELAPSED TIME	71 18.5	121 14.6	147 12.8	317 14.0	105 11.2	37 15.6	798 14.0

TABLE 25
AVERAGE ELAPSED TIME IN MINUTES FOR SEGMENTS OF WEEKDAY FREEWAY
TRIPS IN HOUSTON SURVEY BY TIME SLOT AND ROUTE TYPE

ROUTE TYPE	TIME SLOT								TOTAL
	0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2050	2100- 2359	
NONFREEWAY ¹									
NUMBER OF CASES	24	369	94	135	203	314	199	88	1426
ELAPSED TIME	5.4	9.4	6.3	5.7	6.3	7.3	5.1	6.7	7.1
FREEWAY									
NUMBER OF CASES	12	211	55	77	126	172	109	48	810
ELAPSED TIME	8.0	11.0	13.1	9.5	16.1	11.0	9.7	9.6	11.5
TOTAL									
NUMBER OF CASES	36	580	149	212	329	486	308	136	2236
ELAPSED TIME	6.3	10.0	8.8	7.1	10.1	8.6	6.8	7.7	8.7

¹ EXCLUDES NONFREEWAY SEGMENTS IN NONFREEWAY TRIPS
(I.E., TRIPS WITH N-TRIP SEGMENT SEQUENCE)

TABLE 26
AVERAGE ELAPSED TIME IN MINUTES FOR SEGMENTS OF
WEEKEND FREEWAY TRIPS IN HOUSTON SURVEY BY TIME SLOT AND ROUTE TYPE

ROUTE TYPE	TIME SLOT						TOTAL
	0000- 0829	0830- 1059	1100- 1259	1300- 1759	1800- 2059	2100- 2359	
NONFREEWAY ¹							
NUMBER OF CASES ELAPSED TIME	65 6.2	53 6.3	50 6.6	153 8.8	51 4.7	25 4.7	397 7.0
FREEWAY							
NUMBER OF CASES ELAPSED TIME	39 9.0	31 14.5	27 10.7	88 11.0	29 11.2	13 7.8	227 11.7
TOTAL							
NUMBER OF CASES ELAPSED TIME	104 7.2	84 9.4	77 8.0	241 10.3	80 7.1	38 5.7	624 8.7

¹ EXCLUDES NONFREEWAY SEGMENTS IN NONFREEWAY TRIPS
(I.E., TRIPS WITH "N" TRIP SEGMENT SEQUENCE)

Trip and Segment Idling

The present survey measures idling time in terms of two parameters: the number of stops with engine running per trip or segment and the actual idling time accumulated during periods of idling in excess of about 40 seconds. The mean number of stops per trip by time slot and trip segment string is shown in Tables 27 and 28 for weekday and weekend trips. Tables 29 and 30 show the mean number of stops for trip segments of freeway trips on weekdays and weekends. Tables 31 and 32 show mean measured idling time for weekday and weekend trips while Tables 33 and 34 show similar data for segments of freeway trips.

Elapsed Time Between Trips

Figures 22 and 23 show the distribution of elapsed time between trips for weekday and weekend. The time scale on each figure is broken in several places: at one hour, to enable a more precise breakdown of shorter intertrip times; and at daily intervals from two to six days to enable the agglomeration of larger intertrip times. Tables 35 and 36 show the breakdown of elapsed time from last trip by time slot and purpose of trip for weekday and weekend trips. Since this quantity is not associated with the trip segment structure but is quite clearly associated with trip purpose, we believe this breakdown is more reasonable than that based upon the time slot trip segment string criterion used previously.

In addition to this quantity, the survey results also contain data on the incidence of engine-off stops of less than five minutes. This quantity does not show up as an elapsed time between trips since if such a stop occurred, the computer program merged the two trips into a single record. The incidence of such stops was very meager. Table 37 shows the results for weekdays and weekend trips.

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TABLE 27

DISTRIBUTION OF WEEKDAY TRIPS IN HOUSTON SURVEY BY TRIP
SEGMENT STRING SHOWING AVERAGE NUMBER OF TRIP STOPS WITH ENGINE ON PER TRIP FOR EACH CASE

TRIP SEGMENT STRING	TIME SLOT								TOTAL
	0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2350	
N: NUMBER OF CASES NUMBER OF STOPS (ENGINE ON)	20 4.2	274 8.3	102 4.4	184 3.8	185 5.0	404 6.2	230 3.7	83 4.2	1482 5.5
NFN: NUMBER OF CASES NUMBER OF STOPS	4 4.5	131 10.0	32 6.8	40 5.5	67 7.4	122 8.9	75 5.5	38 5.3	509 7.8
NFNFN: NUMBER OF CASES NUMBER OF STOPS	3 7.3	30 12.2	8 8.2	14 8.3	18 8.5	17 12.1	13 7.6	4 18.2	107 10.3
OTHER: NUMBER OF CASES NUMBER OF STOPS	2 2.5	6 16.2	2 3.5	4 10.2	4 11.2	4 12.0	2 6.5	2 4.0	26 10.2
TOTAL: NUMBER OF CASES NUMBER OF STOPS	29 4.4	441 9.2	144 5.1	242 4.4	274 5.9	547 7.1	320 4.3	127 5.0	2124 6.4

TABLE 28

DISTRIBUTION OF WEEKEND TRIPS IN HOUSTON SURVEY BY TRIP
SEGMENT STRING SHOWING AVERAGE NUMBER OF TRIP STOPS WITH ENGINE ON PER TRIP FOR EACH CASE

TRIP SEGMENT STRING	TIME SLOT						TOTAL
	0000- 0829	0830- 1059	1100- 1259	1300- 1759	1800- 2059	2100- 2359	
N: NUMBER OF CASES NUMBER OF STOPS (ENGINE ON)	44 4.6	97 3.1	123 3.9	250 3.8	80 4.0	26 5.9	620 3.9
NFN: NUMBER OF CASES NUMBER OF STOPS	17 4.7	18 6.1	19 7.0	48 7.2	23 5.5	9 3.7	134 6.2
NFNFN: NUMBER OF CASES NUMBER OF STOPS	8 12.1	5 10.0	5 11.6	17 11.4	2 4.0	1 10.0	38 11.0
OTHER: NUMBER OF CASES NUMBER OF STOPS	2 10.5	1 2.0	0 0.0	2 9.0	0 0.0	1 8.0	6 8.2
TOTAL: NUMBER OF CASES NUMBER OF STOPS	71 5.6	121 3.8	147 4.6	317 4.7	105 4.3	37 5.5	798 4.6

TABLE 29
AVERAGE NUMBER OF ENGINE-ON STOPS FOR SEGMENTS OF WEEKDAY
FREEWAY TRIPS IN HOUSTON SURVEY BY TIME SLOT AND ROUTE TYPE

ROUTE TYPE	TIME SLOT								TOTAL
	0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359	
NONFREEWAY ¹									
NUMBER OF CASES	24	369	94	135	203	314	199	88	1426
NUMBER OF STOPS	2.2	4.4	2.5	2.4	3.0	4.0	2.4	2.8	3.4
FREEWAY									
NUMBER OF CASES	12	211	55	77	126	172	109	48	810
NUMBER OF STOPS	0.2	0.7	1.1	1.0	0.7	0.4	0.6	0.5	0.7
TOTAL									
NUMBER OF CASES	36	580	149	212	329	486	308	136	2236
NUMBER OF STOPS	1.5	3.0	2.0	1.9	2.1	2.7	1.8	2.0	2.4

¹ EXCLUDES NONFREEWAY SEGMENTS IN NONFREEWAY TRIPS
(I.E., TRIPS WITH "N" TRIP SEGMENT SEQUENCE)

TABLE 30
AVERAGE NUMBER OF ENGINE-ON STOPS FOR SEGMENTS OF WEEKEND
FREEWAY TRIPS IN HOUSTON SURVEY BY TIME SLOT AND ROUTE TYPE

ROUTE TYPE	TIME SLOT						TOTAL
	0000- 0829	0830- 1059	1100- 1259	1300- 1759	1800- 2059	2100- 2359	
NONFREEWAY ¹							
NUMBER OF CASES	65	53	50	153	51	25	397
NUMBER OF STOPS	2.8	2.9	3.2	3.2	2.3	2.2	2.9
FREEWAY							
NUMBER OF CASES	39	31	27	88	29	13	227
NUMBER OF STOPS	0.4	0.5	0.8	0.8	0.4	0.2	0.6
TOTAL							
NUMBER OF CASES	104	84	77	241	80	38	624
NUMBER OF STOPS	1.9	2.0	2.4	2.3	1.6	1.5	2.1

¹ EXCLUDES NONFREEWAY SEGMENTS IN NONFREEWAY TRIPS
(I.E., TRIPS WITH "N" TRIP SEGMENT SEQUENCE)

TABLE 31

DISTRIBUTION OF WEEKDAY TRIPS IN HOUSTON SURVEY BY TRIP SEGMENT
 STRING SHOWING AVERAGE MEASURED IDLING TIME IN MINUTES PER TRIP FOR EACH CASE

TRIP SEGMENT STRING	TIME SLOT								TOTAL
	0000-0559	0600-0859	0900-1129	1130-1329	1330-1629	1630-1829	1830-2059	2100-2359	
N: NUMBER OF CASES AVERAGE IDLING TIME	20 0.6	274 1.5	102 0.7	184 0.7	185 1.0	404 0.9	230 0.8	83 0.8	1482 1.0
NFN: NUMBER OF CASES AVERAGE IDLING TIME	4 0.5	131 1.8	32 1.2	40 0.9	67 1.0	122 1.1	75 1.4	38 1.1	509 1.3
NFNFN: NUMBER OF CASES AVERAGE IDLING TIME	3 0.5	30 2.7	8 1.5	14 2.5	18 1.3	17 2.4	13 1.6	4 5.0	107 2.2
OTHER: NUMBER OF CASES AVERAGE IDLING TIME	2 0.5	6 3.8	2 0.5	4 1.2	4 3.0	4 2.0	2 0.5	2 0.5	26 2.0
TOTAL: NUMBER OF CASES AVERAGE IDLING TIME	29 0.6	441 1.7	144 0.8	242 0.8	274 1.1	547 1.0	320 1.0	127 1.0	2124 1.1

TABLE 32

DISTRIBUTION OF WEEKEND TRIPS IN HOUSTON SURVEY BY TRIP SEGMENT
 STRING SHOWING AVERAGE MEASURED IDLING TIME IN MINUTES PER TRIP FOR EACH CASE

TRIP SEGMENT STRING	TIME SLOT						TOTAL
	0000-0829	0830-1059	1100-1259	1300-1759	1800-2059	2100-2359	
N: NUMBER OF CASES AVERAGE IDLING TIME	44 1.0	97 1.2	123 1.1	250 0.9	80 0.8	26 1.6	620 1.0
NFN: NUMBER OF CASES AVERAGE IDLING TIME	17 1.0	18 0.5	19 0.5	48 1.1	23 1.3	9 0.8	134 0.9
NFNFN: NUMBER OF CASES AVERAGE IDLING TIME	8 0.5	5 0.5	5 0.9	17 1.7	2 0.5	1 3.5	38 1.2
OTHER: NUMBER OF CASES AVERAGE IDLING TIME	2 0.5	1 0.5	0 0.0	2 0.5	0 0.0	1 0.5	6 0.5
TOTAL: NUMBER OF CASES AVERAGE IDLING TIME	71 1.0	121 1.1	147 1.0	317 1.0	105 0.9	37 1.5	798 1.0

TABLE 33
AVERAGE MEASURED IDLING TIME IN MINUTES FOR SEGMENTS
OF WEEKDAY FREEWAY TRIPS IN HOUSTON BY TIME SLOT AND ROUTE TYPE

ROUTE TYPE	TIME SLOT								TOTAL
	0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359	
NONFREEWAY ¹									
NUMBER OF CASES	24	369	94	135	203	314	199	88	1426
AVG IDLING TIME	0.5	1.3	0.7	0.9	0.7	0.8	0.9	1.0	1.0
FREEWAY									
NUMBER OF CASES	12	211	55	77	126	172	109	48	810
AVG IDLING TIME	0.5	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.5
TOTAL									
NUMBER OF CASES	36	580	149	212	329	486	308	136	2236
AVG IDLING TIME	0.5	1.1	0.7	0.8	0.7	0.7	0.8	0.8	0.8

¹ EXCLUDES NONFREEWAY SEGMENTS IN NONFREEWAY TRIPS
(I.E., TRIPS WITH "N" TRIP SEGMENT SEQUENCE)

TABLE 34

AVERAGE MEASURED IDLING TIME IN MINUTES FOR SEGMENTS
OF WEEKEND FREEWAY TRIPS IN HOUSTON BY TIME SLOT AND ROUTE TYPE

ROUTE TYPE	TIME SLOT						TOTAL
	0000- 0829	0830- 1059	1100- 1259	1300- 1759	1800- 2059	2100- 2359	
NONFREEWAY ¹							
NUMBER OF CASES	65	53	50	153	51	25	397
AVG IDLING TIME	0.6	0.5	0.4	0.7	0.8	0.7	0.7
FREEWAY							
NUMBER OF CASES	39	31	27	88	29	13	227
AVG IDLING TIME	0.5	0.5	0.5	0.6	0.5	0.5	0.6
TOTAL							
NUMBER OF CASES	104	84	77	241	80	38	624
AVG IDLING TIME	0.6	0.5	0.5	0.7	0.7	0.7	0.5

¹ EXCLUDES NONFREEWAY SEGMENTS IN NONFREEWAY TRIPS
(I.E., TRIPS WITH "N" TRIP SEGMENT SEQUENCE)

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FIGURE 22
DISTRIBUTION OF ELAPSED TIME BETWEEN TRIPS, WEEKDAY

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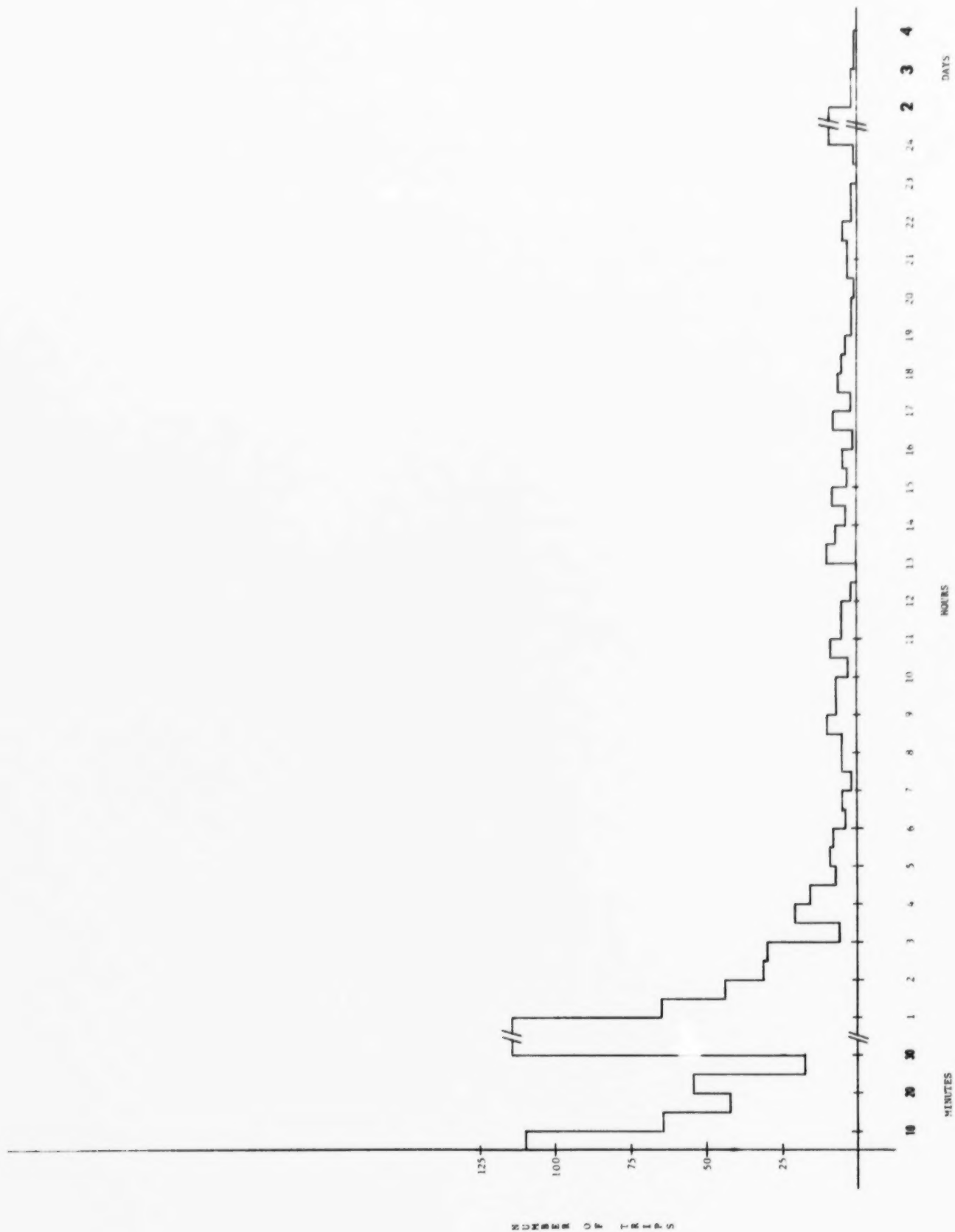


FIGURE 23
DISTRIBUTION OF ELAPSED TIME BETWEEN TRIPS, WEEKEND

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TABLE 35

AVERAGE ELAPSED TIME SINCE LAST TRIP FOR WEEKDAY
TRIPS IN HOUSTON SURVEY BY TIME SLOT AND PURPOSE

PURPOSE OF TRIP	TIME SLOT								TOTAL
	0000- 0559	0600- 0859	0900- 1129	1130- 1329	1330- 1629	1630- 1829	1830- 2059	2100- 2359	
GO HOME	12 2:28	17 5:56	15 2:19	24 1:09	72 3:29	311 4:39	134 2:04	84 2:18	669 3:32
GO TO WORK	7 10:10	351 12:34	31 4:41	63 1:05	42 2:23	9 1:35	5 9:30	7 5:41	515 9:31
BUSINESS	0 0:00	46 8:39	56 1:45	80 3:22	88 2:12	44 4:06	15 1:06	6 2:39	335 3:29
SHOPPING	7 8:11	21 10:16	31 6:34	64 4:15	56 3:00	114 3:39	92 1:58	10 2:15	395 3:54
CHURCH, SCHOOL, ETC.	0 0:00	2 12:50	5 12:21	3 17:40	5 2:08	14 7:19	7 1:22	1 2:15	37 7:08
RECREATION	3 4:05	4 2:38	6 3:26	8 3:41	11 3:38	55 2:42	67 1:11	19 4:11	173 2:26
TOTAL	29 5:52	441 11:42	144 3:55	242 2:58	274 2:47	547 4:13	320 1:55	127 2:47	2124 5:01

TABLE 36

AVERAGE ELAPSED TIME SINCE LAST TRIP FOR WEEKEND
TRIPS IN HOUSTON SURVEY BY TIME SLOT AND PURPOSE

PURPOS PURPOSE OF TRIP	TIME SLOT						TOTAL
	0000- 0829	0830- 1059	1100- 1259	1300- 1759	1800- 2059	2100- 2359	
GO HOME	30 6:20	27 0:54	49 0:58	115 1:43	43 3:13	21 6:12	285 2:35
GO TO WORK	14 11:09	8 9:38	4 0:56	8 6:55	4 1:50	2 19:38	40 8:28
BUSINESS	4 12:36	15 5:29	8 13:40	17 4:21	1 6:15	0 0:00	45 7:09
SHOPPING	9 8:19	42 7:01	56 5:16	107 3:29	16 2:36	5 9:21	235 4:48
CHURCH, SCHOOL, ETC.	1 7:15	16 12:41	2 15:00	5 1:14	2 11:00	0 0:00	26 10:19
RECREATION	13 4:33	31 6:14	28 4:32	65 2:41	39 2:33	9 2:08	167 3:18
TOTAL	71 7:42	121 6:18	147 4:09	317 2:47	105 2:56	37 6:22	798 4:11

TABLE 37

NUMBER OF CASES OF ENGINE-OFF STOPS
FOR WEEKDAY AND WEEKEND TRIPS IN HOUSTON SURVEY

NUMBER OF STOPS	NUMBER OF TRIPS	
	WEEKDAY	WEEKEND
0	1981 (93%)	725 (91%)
1	143 (7%)	73 (9%)

Parking

The results obtained on parking habits during the survey indicate a high likelihood that most residents in the Houston area leave their cars outdoors both at night and between trips. Table 38 shows the results for weekdays and weekends. Survey participants were told that only closed garages constituted indoor parking.

TABLE 38

INDOOR AND OUTDOOR PARKING OVERNIGHT AND BETWEEN
TRIPS FOR WEEKDAYS AND WEEKEND DAYS IN HOUSTON SURVEY

	INDOOR	OUTDOOR
WEEKDAYS:		
BETWEEN TRIPS	154 (7.2%)	1974 (92.8%)
OVERNIGHT	144 (24.8%)	346 (75.2%)
WEEKEND DAYS:		
BETWEEN TRIPS	44 (5.5%)	754 (94.5%)
OVERNIGHT	34 (18.5%)	150 (81.5%)

Overnight Fuel Tank Readings

Table 39 shows the percentage of fuel tank readings at the empty, one-quarter, one-half, three-quarter, and full levels for weekdays and weekend days. Survey participants were asked to note the reading at the start of the day's travel.

TABLE 39

OVERNIGHT FUEL TANK READINGS FOR WEEKDAYS AND WEEKEND DAYS IN
HOUSTON SURVEY (EXPRESSED AS A PERCENTAGE OF CAR DAYS FOR THE TWO CATEGORIES)

READING	PERCENTAGE OF CAR-DAYS	
	WEEKDAY	WEEKEND
EMPTY	6.2%	4.6%
1/4	22.4%	22.7%
1/2	22.9%	31.8%
3/4	23.1%	22.7%
FULL	25.4%	18.2%

Use of Freeways Versus Surface Streets

Approximately 70% of all weekday trips and 78% of all weekend trips in the Houston survey were made entirely on surface streets. The previous tables showing the breakdown of trip descriptor variables by trip segment string indicate that the freeway trip is both larger and carried out at a greater average speed than the nonfreeway trip. As in the Los Angeles study, Figures 24 through 31 were prepared to determine whether the driver tends to use a freeway because of the greater distance he must cover or because of the speed advantage he may obtain. The figures show the distribution of trip distance for nonfreeway and freeway trips by three-mile increments within each of the eight time slots. While all the charts are not entirely parallel, it is clear that they tend to show a high incidence of short trips and a lower incidence of long trips. In mathematical terms, they all basically resemble

exponential probability frequency functions (only the figure for time slot two (Figure 25) departs markedly from this appearance). Furthermore, although the distributions of freeway trips appear to be approximately bell-shaped, the higher frequency of short nonfreeway trips controls the overall exponential appearance of the figures.

The distinction between short nonfreeway trips and longer freeway trips in the Houston survey is not as clearly marked as in the Los Angeles survey however. To some extent this may be the result of the differences in the freeway systems of the two cities. Los Angeles has fairly complete grid coverage by freeways while the system in Houston is not yet complete. Therefore, some of the long nonfreeway trips taken by Houston participants may simply have been forced upon drivers by the lack of a freeway between their origin and destination. Nevertheless, during the survey period, of the approximately 22,700 miles driven during the survey, about 12,800 (56%) of them were on trips involving freeways and over 8000 were actual freeway miles.

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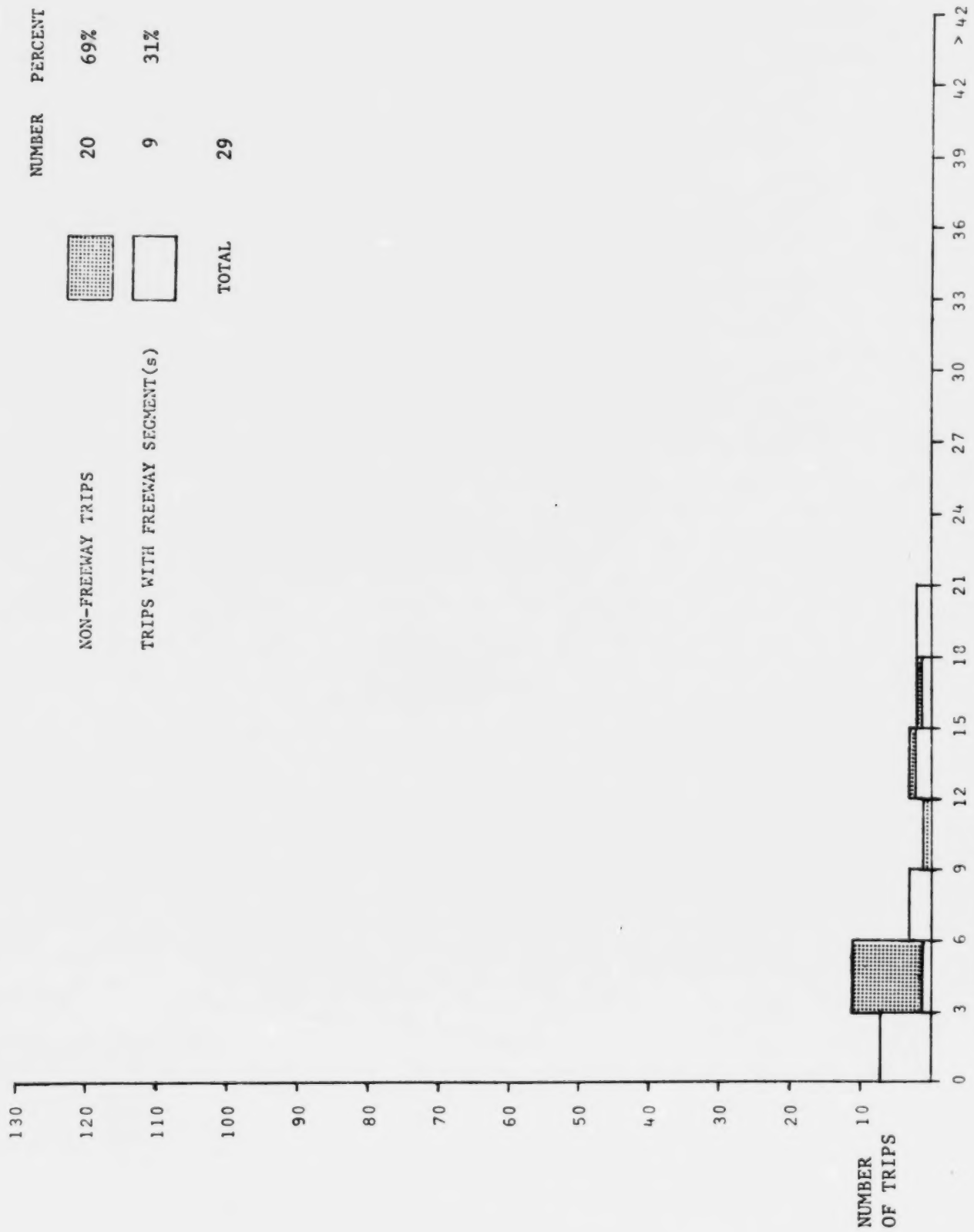


FIGURE 24
DISTRIBUTION OF TRIP DISTANCE IN TIME SLOT ONE (0000 - 0559)
SHOWING DIVISION BETWEEN FREEWAY AND NON-FREEWAY TRIPS

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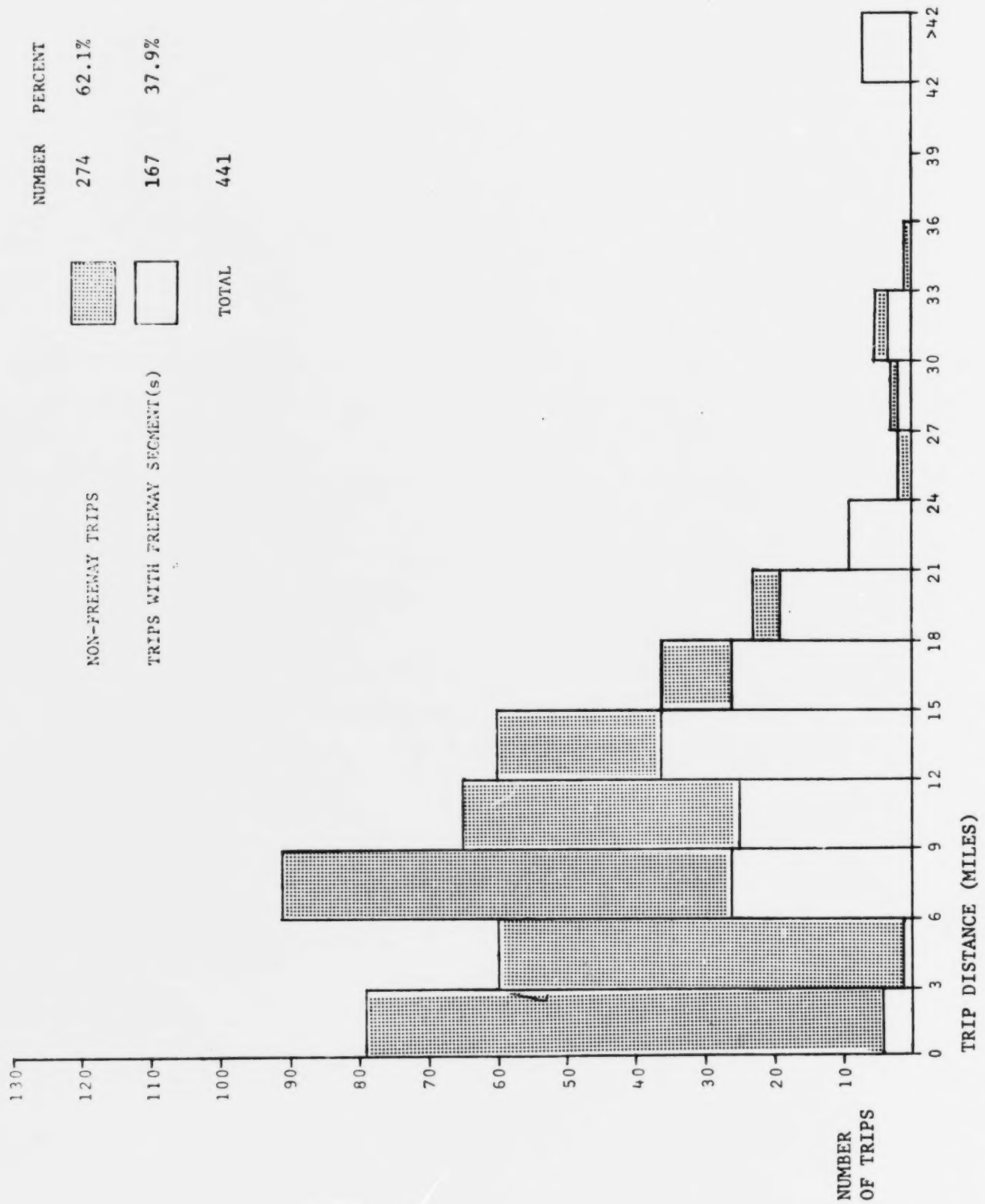


FIGURE 25

DISTRIBUTION OF TRIP DISTANCE IN TIME SLOT TWO (0600 - 0859)
SHOWING DIVISION BETWEEN FREEMAY AND NON-FREEMAY TRIPS

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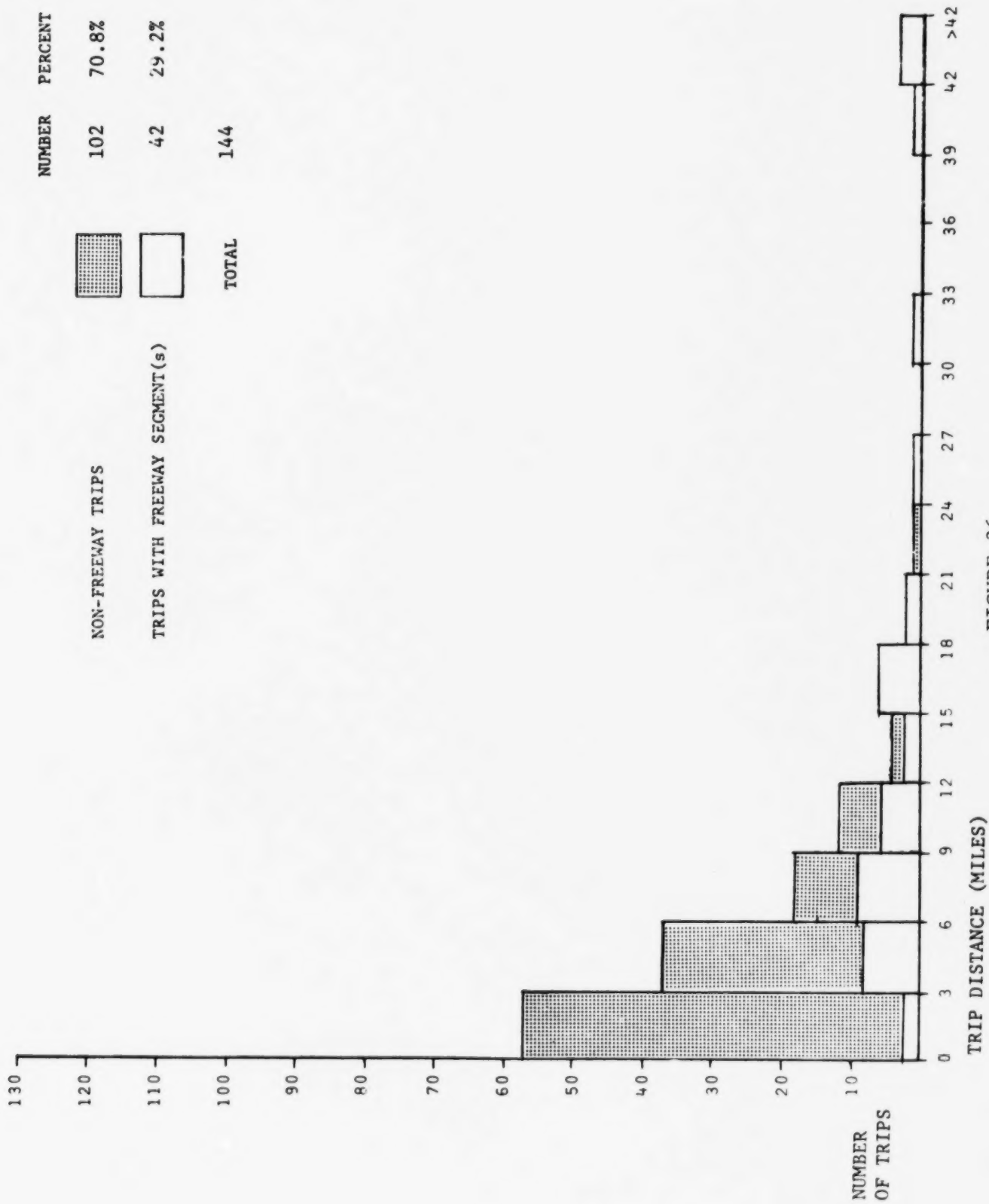
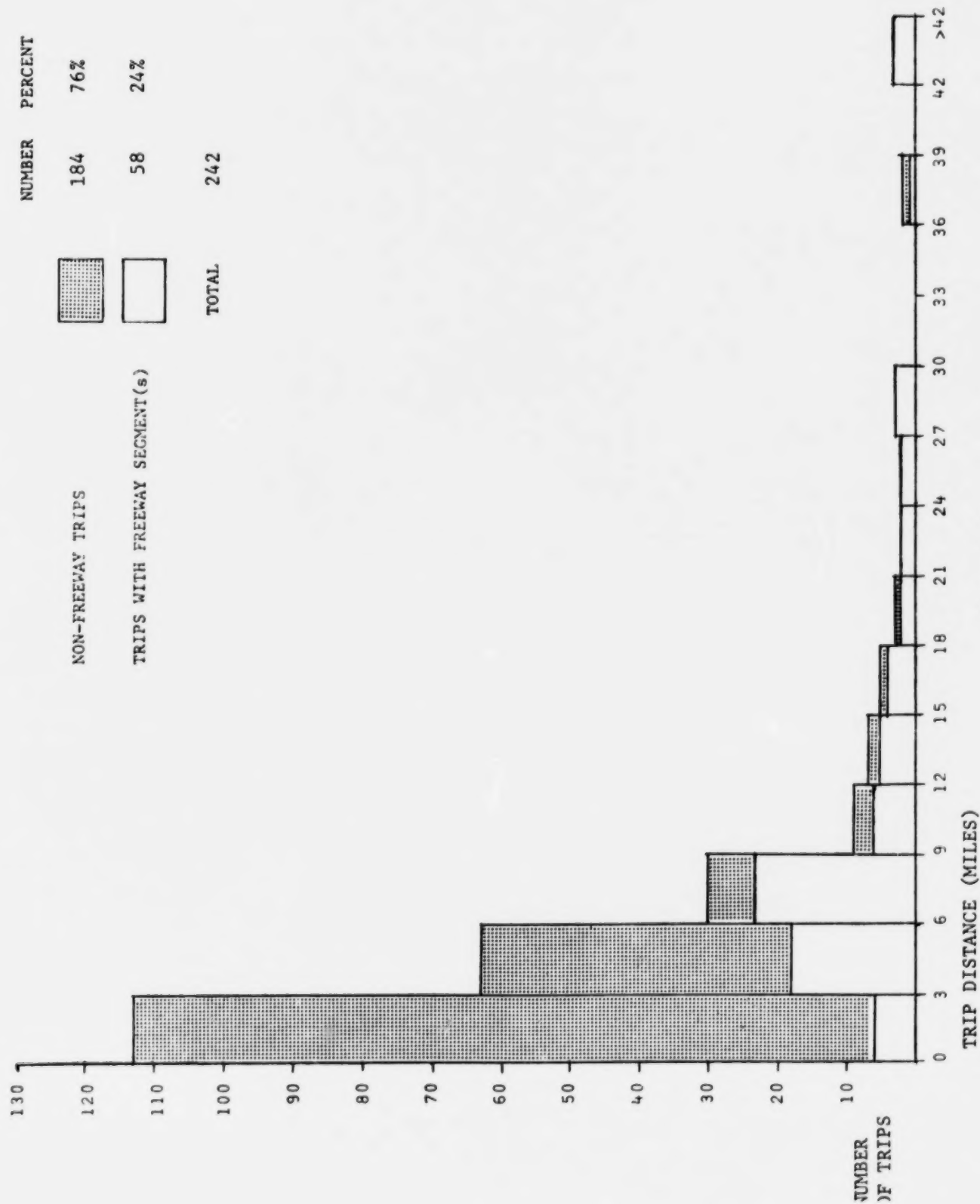
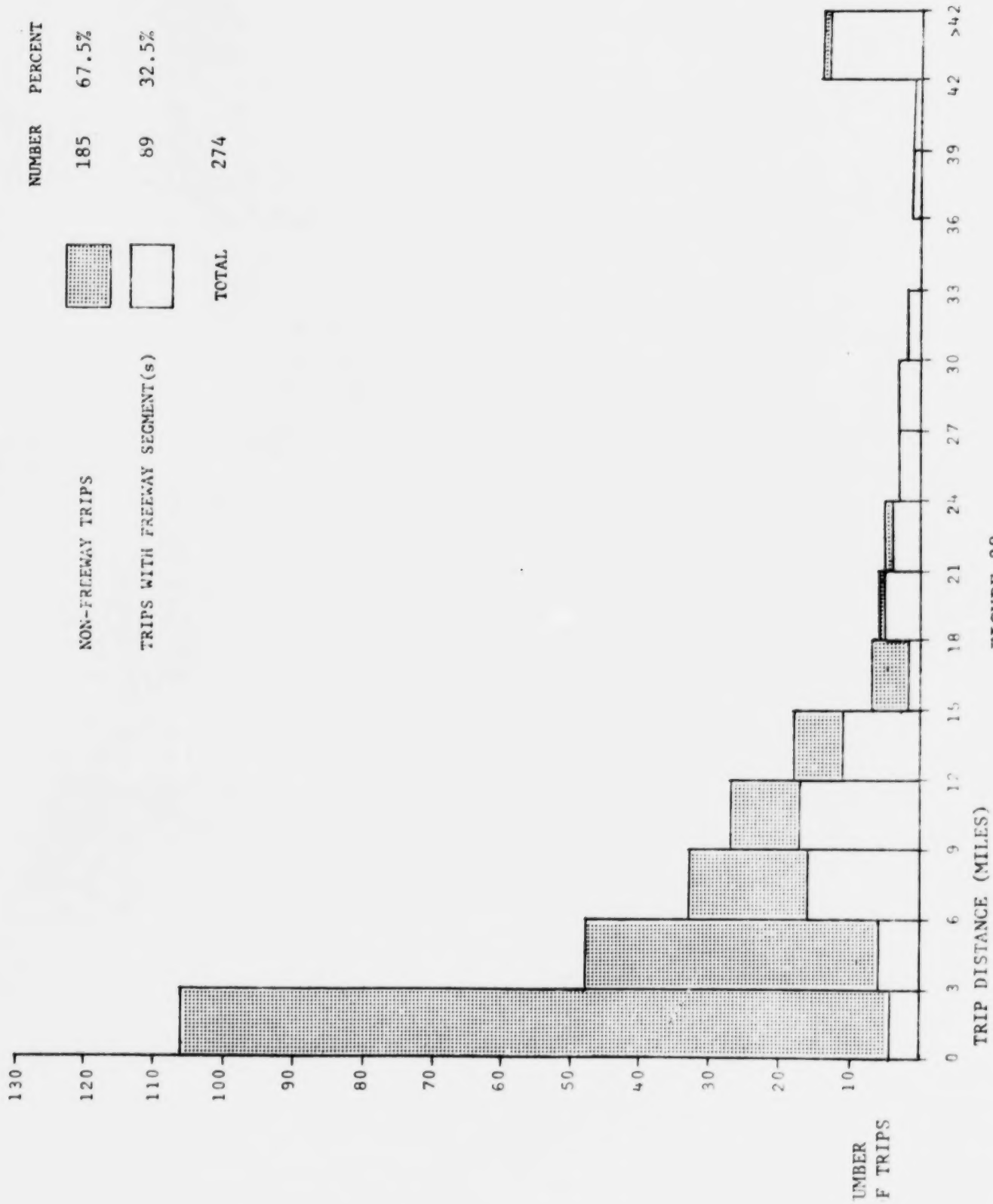


FIGURE 26

DISTRIBUTION OF TRIP DISTANCE IN TIME SLOT THREE (0900 - 1129)
SHOWING DIVISION BETWEEN FREEWAY AND NON-FREEWAY TRIPS





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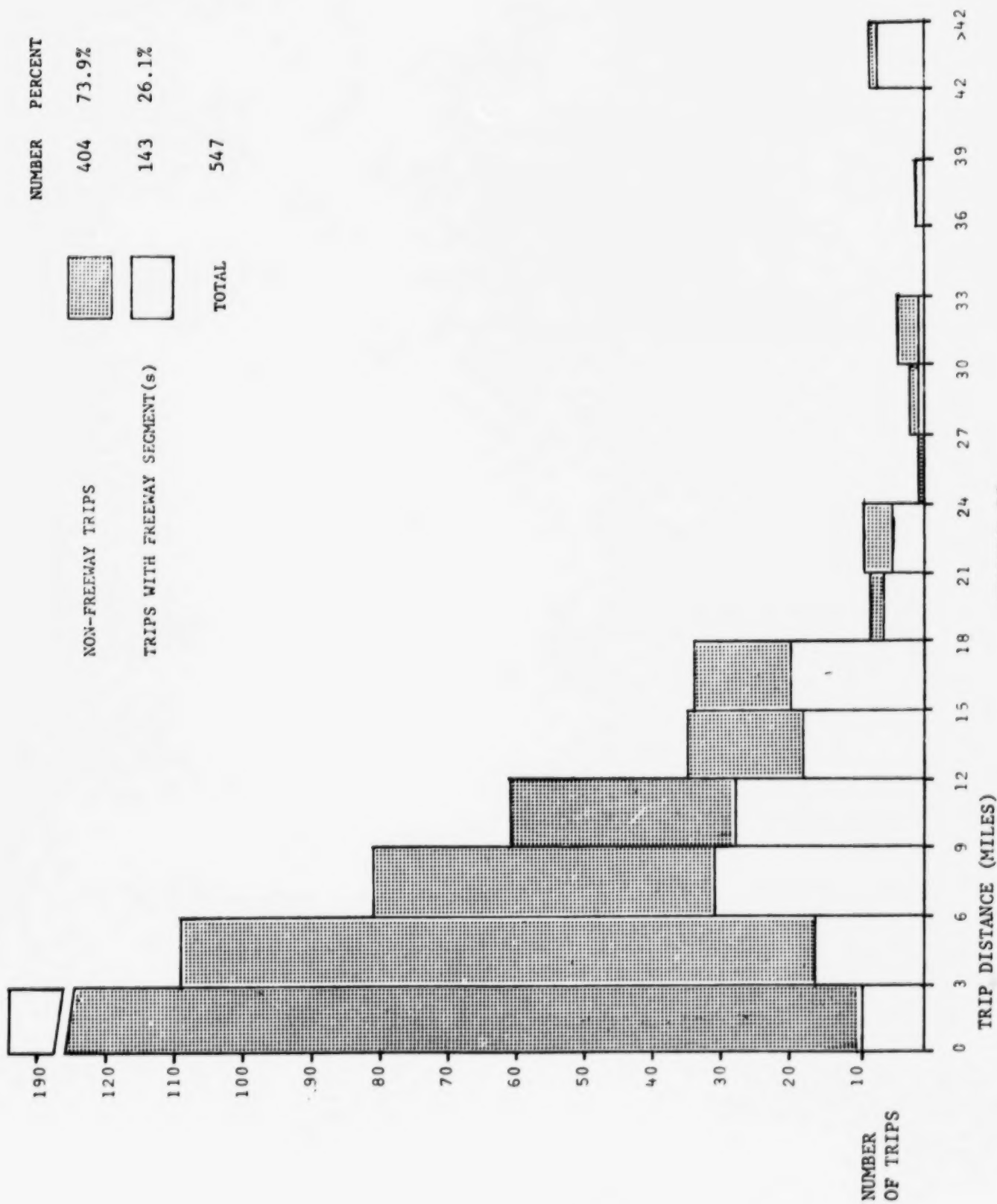


FIGURE 29

DISTRIBUTION OF TRIP DISTANCE IN TIME SLOT SIX (1630 - 1829)
SHOWING DIVISION BETWEEN FREEWAY AND NON-FREEWAY TRIPS

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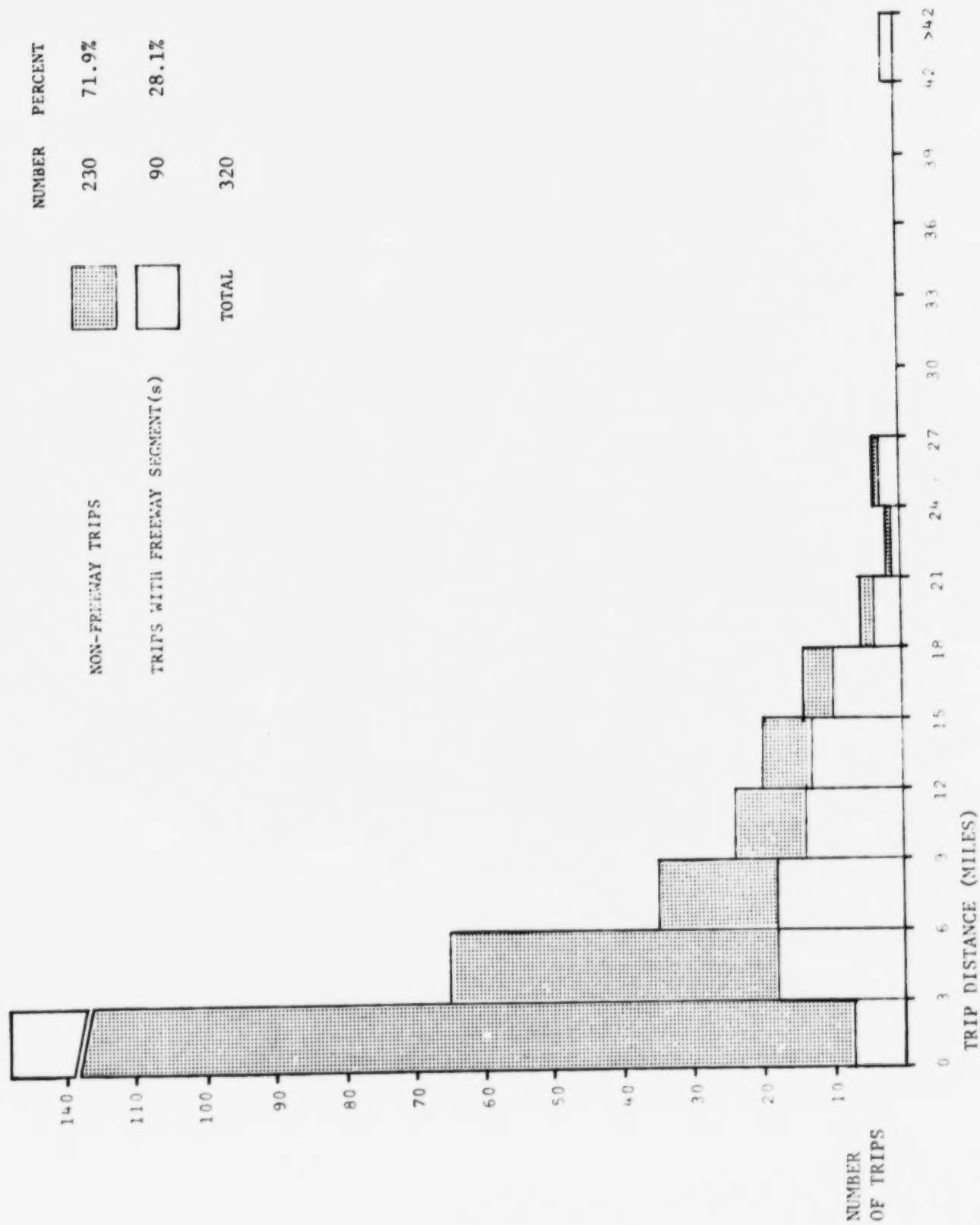


FIGURE 30

DISTRIBUTION OF TRIP DISTANCE IN TIME SLOT SEVEN (1830 - 2059)

SHOWING DIVISION BETWEEN FREEWAY AND NON-FREEWAY TRIPS

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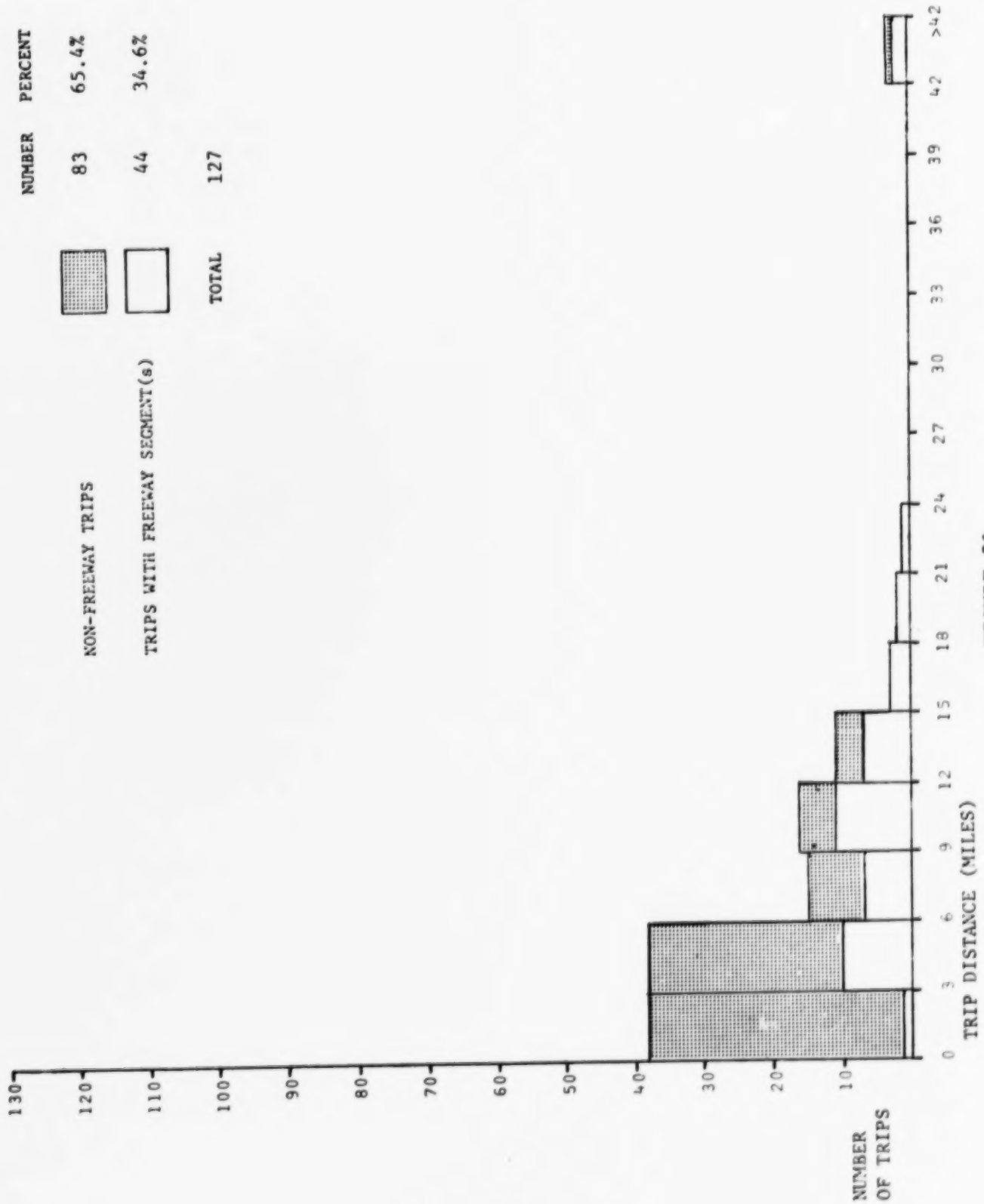


FIGURE 31
 DISTRIBUTION OF TRIP DISTANCE IN TIME SLOT EIGHT (2100 - 2359)
 SHOWING DIVISION BETWEEN FREEWAY AND NON-FREEWAY TRIPS

COMPARISON OF HOUSTON AND LOS ANGELES SURVEY RESULTS

This section of the report compares the results obtained in the Los Angeles and Houston surveys. It is divided into three discussion areas -- n-trip day patterns, automobile utilization, and trip descriptors. Comparisons between the two surveys employ two basic statistical approaches. The principal approach compares the distributions of specific variables obtained in the samples of the two cities. Formally stated, the basic hypothesis being tested in each case is whether the two samples are drawn from populations that are homogeneous with respect to that variable. Since the Driving Patterns Survey is concerned with overall spectrum of driving characteristics rather than with statistical averages describing those characteristics, we believe that the comparison of distributions provides a more valid basis for statistical inference than the comparison of sample means and standard deviations. Therefore, if statistical tests applied to the two samples do not reject the hypothesis of homogeneity, no further testing is carried out. If the hypothesis is rejected, then an examination of the data to determine the reason for rejection is made and weaker (perhaps less relevant) hypotheses about the equality of sample means are made and tested. In all statistical tests described, we have used an α of 0.05. Thus, if a test indicates that a hypothesis should be rejected, the probability is only 0.05 that the test has incorrectly rejected a valid hypothesis.

The comparisons of distributions for homogeneity employ the Kolmogorov-Smirnov statistic for variables with underlying distributions that are continuous and the Chi-square Test of Homogeneity for variables with discrete distributions. Other tests used for comparisons are described as they are used.

N-Trip Day Patterns

Table 40 shows the percentage of total n-trip days and total car-weekdays represented by those cars that drove the n-trip patterns. (In Volume 6 results for Los Angeles indicated n-trip pattern days as a percentage of total

car-days. The values in Table 40 have been normalized to total car-weekdays to make them comparable to the Houston results.)

TABLE 40

N-TRIP PATTERN CAR-DAYS AS A PERCENTAGE OF ALL N-TRIP DAYS
AND ALL CAR-WEEKDAYS IN THE LOS ANGELES AND HOUSTON SURVEYS

N-TRIP PATTERN	PERCENT OF N-TRIP DAYS		PERCENT OF CAR-WEEKDAYS	
	HOUSTON	LOS ANGELES	HOUSTON	LOS ANGELES
2	64% - 86%	44% - 54%	13.5% - 18.1%	8.8% - 11.0%
3	45%	18%	5.0%	2.3%
4 (Evening)	29%	12%	5.3%	2.2%
4 (Noon)	14%	13%	2.7%	2.3%
5	23%	16%	3.1%	1.9%

The results shown in Table 40 strongly indicate that the typical n-trip patterns are representative of a greater portion of the Houston sample than they are of the Los Angeles sample. Approximately 30% of all the car-weekdays in Houston were n-trip patterns compared to only 18% in Los Angeles. A Chi-square test of the number of n-trip pattern car-days versus nonpattern car-days indicates a highly significant difference between the two cities.

No ready explanation for this difference comes to mind. Los Angeles and Houston are similar cities in many ways: Both are dynamically growing cities with populations closely tied to the use of automobiles since other forms of inter-urban transportation are not well developed; both have suburban areas that are large compared to the central city. One possible explanation lies in the season of the year during which each city was surveyed. The Los Angeles survey took place during the summertime when daylight hours are longer and the automobile is more likely to be used. The Houston survey was in the winter and, even though the temperatures were by no means cold when compared to northern

cities, the daylight hours were of shorter duration -- perhaps creating less demand for evening and night trips. If such were the case, fewer number of trips would be made per day by each automobile, thereby increasing the likelihood that the daily pattern would fit one of the typical n-trip patterns. This explanation is weakened, however, by the results, discussed below, which show no significant differences between Los Angeles and Houston in the time slot loading or the start time distribution of trips or in the incidence of n-trip days for all values of n.

Automobile Utilization

Automobile utilization is characterized by the number of trips driven per day, the times at which they are driven, their purposes, and the types of routes taken. Each of these factors was tested for homogeneity between the two cities. The similarities are startling and outweigh, in the minds of the authors, the differences.

The number of n-trip days in each city were compared by means of a Chi-square test. The hypothesis of homogeneity was not rejected as a result. It is interesting to note that 17 trips per day was the maximum number in each city.

A Chi-square test was also made of the division of trips between weekdays and weekend days in the two cities. The hypothesis of homogeneity had to be rejected here because there was a greater number of weekend trips in Houston than would be expected if the proportions were the same as in Los Angeles.

The time distribution of trips was tested first by time slot, then by the distribution of trip start times by 15-minute intervals throughout the day for both weekday and weekend trips. The time slot loadings of trips were tested with a Chi-square test. For weekday trips the hypothesis of homogeneity was accepted; in fact, the value of Chi-square calculated was not even significant at $\alpha = 0.70$. The weekend time slot loading was a different story. Differences were detected in all time slots and a significant overall difference was indicated sufficient to reject the hypothesis of homogeneity.

The discrepancy between weekday similarity and weekend dissimilarity need not surprise the reader however. Weekday travel tends, in the majority of cases, to be dictated by the work schedule. This varies little from city to city. Weekend travel, on the other hand, is more likely to be at the discretion of the individual. Furthermore, it is regulated to a degree by the time of year and the prevailing weather. Consequently, given the different reasons during which the two cities were surveyed, it is not surprising that the time distribution of weekend travel should be different in each.

The test on the distribution of trip start times by 15-minute increments was made using the Kolmogorov-Smirnov statistic. This statistic compares the maximum percentage deviation between the cumulative distribution functions for two samples against a computed value based on sample size. The computed value varies with the value of α chosen for the test. No significant difference was detected between the weekday samples for Los Angeles and Houston. As might be expected from the differences detected in time slot loading, a significant difference was detected in the weekend distribution of trip start times.

An interestingly significant difference between the two samples was discovered in the distribution of trip purpose. The two cities showed significant differences here on both weekday and weekend travel. During the week, drivers in Los Angeles took proportionately fewer business and educationally related trips and proportionately more recreation trips than their Houston counterparts. On weekends, Los Angeles drivers were again less likely to take business or educational trips and in addition less likely to go to work. While there was a greater tendency to take recreation trips, it was not as great proportionately as on weekdays. It is difficult to assess the meaning of these differences. Are they a reflection on the social values of Los Angeles residents or are they the result of seasonal differences between cities? Perhaps they are caused by differences in interpretation, since the driver had to define the trip purpose to his own satisfaction and enter it in his log book.

Of more immediate pertinence to the study is the division of trips between surface streets and freeways. Chi-square tests on the trip segment string distribution for weekday and weekend trips result in the rejection of the hypothesis that the Los Angeles and Houston samples are homogeneous. The reason for this rejection is the greater incidence of freeway trips with a segment configuration other than nonfreeway-freeway-nonfreeway. Chi-square tests examining only the distribution of nonfreeway trips and freeway trips regardless of segment configuration result in the acceptance of the basic hypothesis.

The rejection of the hypothesis in the initial tests can be explained in major part by the configuration of the freeway system in Houston. Unlike Los Angeles, with its fairly complete grid coverage of the city and a substantial number of alternate routes available between origins and destinations, Houston has several gaps in its system as well as less overall coverage. Consequently, a trip may be broken into several freeway segments separated by surface street travel simply because the freeway link is not yet complete. The second test, comparing only freeway and nonfreeway trips rather than segment configurations, indicates that within the two cities the tendency is to use surface streets for the short trips that constitute the bulk of all travel, reserving freeways for longer trips.

Trip Descriptors

While the tests on variables related to n-trip patterns and automobile utilization showed surprising homogeneity between the two cities, the statistics describing trips themselves do not show the same characteristic as strongly. The trip descriptors we will discuss are elapsed time between trips, trip distance, trip elapsed time, trip stops with engine running and trip average speed. In addition, tests were made on the results of indoor-outdoor parking and overnight fuel tank readings.

The distributions of elapsed time between trips for weekday and weekend trips were tested for homogeneity using the Kolmogorov-Smirnov statistic. No significant differences were found between the Los Angeles and Houston samples for either. In view of the importance of "soak time" to the problem of emissions, this finding would seem to be significant.

A comparison of trip distances is made difficult by the fact that in the Los Angeles analysis distances greater than 50 miles were arbitrarily removed from the data base because of computer storage problems (See Volume 0, p. 3-11A). In order to compare the values in the Houston sample with those in the Los Angeles sample, it was necessary to remove values above 50 miles from these distributions. The resulting adjusted average distances are 7.03 miles for weekday trips and 5.50 miles for weekend trips. The associated standard deviations are 6.92 and 7.10 miles respectively.

The Kolmogorov-Smirnov test for the homogeneity of the samples with respect to weekday trip distance rejected the basic hypothesis using both the raw and the adjusted Houston values. Although the average distances (7.03 miles in Houston and 7.25 miles in Los Angeles) seem close and the standard deviations (6.92 miles in Houston and 8.32 miles in Los Angeles) seem to indicate that each mean lies within one standard deviation of the other, the strongest hypothesis that can be accepted statistically is that the samples are drawn of populations that have the same mean but unequal variances. This is so because of the large sample sizes involved and the fact that the distributions are highly skewed. The distributions of trip distances in the samples are quite different. The Los Angeles sample shows a proportionately larger number of short trips than the Houston sample. The Houston sample, on the other hand, outweighs the Los Angeles sample in trips between 11 and 30 miles.

A Kolmogorov-Smirnov test on the distribution of weekend trip distances using unadjusted Houston values rejects the hypothesis of homogeneous samples. However, when the Houston values are adjusted to remove trips over 50 miles, the hypothesis is accepted.

Because weekday trip distances are distributed differently in the two cities, it is reasonable to expect that elapsed times for weekday trips should also be differently distributed. Again the Houston data for weekdays must be adjusted to remove time values in excess of two hours. These values were omitted in the Los Angeles results because of computer storage limitations. The resulting distribution shows a mean elapsed time of 17.02 minutes and standard deviation of 15.19 minutes. Testing this distribution against the Los Angeles data we are forced to reject the basic hypothesis. The reason here is the proportionately higher incidence of trip times between four and 14 minutes in Los Angeles as compared to Houston. Weakening our hypothesis somewhat, we can accept one stating that the samples are drawn from populations having the same means and unknown but equal variances.

The distributions of weekend trip elapsed times are homogeneous between the two cities even if the Houston data are not adjusted. There is only one value of weekend trip elapsed time greater than two hours in the Houston sample.

Tests on the distributions of trip stops with engine running for both weekday and weekend trips result in the rejection of the basic hypothesis of homogeneity. Here Chi-square tests were used because of the discrete distributions. Further tests of hypotheses about the equality of the means are also rejected significantly. The reason appears to be a preponderance of large values in the Los Angeles data. The mean values for the variables are, for weekdays, 8.64 in Los Angeles and 6.34 in Houston and for weekends, 6.50 in Los Angeles and 4.61 in Houston. The weekday standard deviations are 7.77 and 5.74 for Los Angeles and Houston respectively, and the weekend values are 7.27 and 4.39 respectively for the same cities. Thus, we see that Los Angeles drivers experience more stops per trip on the average and the variability in the number of stops on any trip is likely to be larger than in Houston.

Turning to average speeds, it is somewhat surprising to find that this variable, which of all the variables studied has the only somewhat symmetrically shaped frequency distribution, and which has average values that are quite close in

the two cities, nevertheless fails in the test of homogeneity. Such, however, is the case for weekday values. Again, the strongest hypothesis that can be accepted statistically is that the samples are drawn from populations with equal means and unknown as well as unequal variances. This, even though the standard deviations may be only 1.16 miles per hour. The cause for rejection is that in the Houston sample the values are more closely concentrated around the mean than they are in the Los Angeles sample. Furthermore, the large sample size means that the sample variances are very close to the population variances and the 1.16 miles per hour difference must be treated as very significant.¹ The distribution of average speeds on the weekend in Houston and Los Angeles, however, do pass the Kolmogorov-Smirnov test for homogeneity.

The distributions of indoor and outdoor parking in the two samples was tested twice, first for parking between trips and second for overnight parking. For between-trip parking, the basic hypothesis of homogeneity was rejected because of a proportionately greater amount of indoor parking in Los Angeles than in Houston. The hypothesis was rejected for both weekday and weekend samples. This is somewhat surprising to the authors, since the number of cars that parked indoors between trips was only 8.5% of the total number of trips. On the other hand, tests on both weekday and weekend distributions of overnight parking indoors and out resulted in acceptance of the basic hypothesis of homogeneity between the two cities.

The final variable that was tested was the overnight fuel tank readings. Here the basic hypothesis was accepted for both the weekday and weekend distributions.

¹ In the F-test for equality of variance, the greatest F ratio that can be accepted at the $\alpha = 0.05$ level (using a two-tailed test) is 1.14 with the appropriate degrees of freedom. The calculated value of the ratio for the two samples is 1.25.

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Conclusions

The comparisons just described show interesting similarities between the Los Angeles and Houston samples. The degree of stability in some of the more basic statistics between the two cities, if duplicated in the remaining four cities, makes it likely that nationally valid conclusions can be drawn from the Driving Patterns Survey. The possible effects of seasonal variance, alluded to in explaining some of the differences noted, will be watched with care in the subsequent cities since they will form an orderly transition from cold northern winter in Cincinnati to early spring in Chicago to early summer in the Twin Cities, and finally to late summer in New York City.

APPENDIX

HOUSTON SURVEY PROCEDURES

The survey procedure was designed to obtain data from which typical driving patterns could be derived. Three basic steps were taken in the data gathering phase of the survey: design of the survey sample; selection of the survey participants; and collection of data. Subsequent sections of this Appendix cover each of these steps in detail.

SAMPLE DESIGN

The sample for the Houston Driving Patterns Survey was designed to obtain data on an adequate number of trips to ensure that description of trip variables would be statistically accurate. Fifty Tachograph recording devices previously employed during the Los Angeles Driving Patterns Survey were used to collect data from fifty participating automobiles for one week; on the basis of Houston's population, it was determined that data from 150 vehicles would be a representative sample.

As in the Los Angeles survey, the sample was stratified four ways in terms of residence type (single family and multiple family dwelling) and car ownership (single car and multiple car). These stratification criteria were based on data from the continuing Los Angeles Regional Traffic Study (LARTS), which indicates that trip generation rates for automobiles can be correlated with residence type and car ownership.

The proposed stratification in Los Angeles was based on 1960 Census data. As the study there progressed, however, application forms from prospective participants showed clearly that the 1968 population had changed markedly from the 1960 population with respect to residence type and car ownership. This change necessitated a modification to the stratification of the Los Angeles sample.

Based upon our experience in Los Angeles relative to changes in population, it was decided to stratify the sample for the Houston survey according to data provided by application forms received from prospective participants. Percentages in each of the cells in the matrix in Table 1 are representative averages of the information obtained from the 11 participating organizations in Houston.

TABLE A-1
STRATIFICATION OF THE SAMPLE FOR THE HOUSTON DRIVING PATTERNS SURVEY

RESIDENCE TYPE	AUTOMOBILES PER HOUSEHOLD	
	ONE	TWO OR MORE
Single Family	23%	56%
Multiple Family	13%	8%

PARTICIPANT SELECTION

The method by which SDC selected participants in the survey was chosen to obtain a representative cross-section of the Houston population. A list of large industrial and commercial organizations in the area was provided by the Houston Chamber of Commerce. From this list, 24 firms were contacted and briefed on the nature of the survey. Of the firms contacted, nine agreed to participate.

In some cases labor disputes or changes in company policies with regard to surveys reduced the original number of participating organizations to six. Five additional companies were recruited for the survey during the installation team's visit in January 1969. Those companies ultimately participating in the Houston survey were G. W. Murphy Industries, Inc., Hughes Tool Company/Oil Tool Division, Anheuser-Busch, Inc., Humble Oil and Refining Company, The Houston Chronicle, Continental Emsco, Dresser Systems, Inc., AMF Tuboscope, Inc.,

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American General Insurance Company, Brown & Root, Inc., and Phillips Petroleum Company.

Individual volunteers from within each company were recruited by means of Information/Questionnaire Packets which were distributed among the employees (see Volume 0, Appendix II). All the organizations were encouraged to seek as many volunteers as possible; however, the number to be solicited as well as the method to be used to distribute the Information/Questionnaire Packets were left to the discretion of each organization. Generally, those organizations with smaller populations (85 to 500 people) chose to canvas all of their employees for volunteers; those with a larger population (more than 500 people) decided upon some form of random method of distribution, e.g., distribute one packet to every third name in the telephone book, distribute packets to all personnel who parked their automobiles in the company garage, etc.

A total of 2875 packets were distributed within the participating organizations. Of that number 450 individuals volunteered to participate, from which 133 met the stratification scheme and were chosen as the survey sample (see Table 2).

DATA COLLECTION

The data collection effort in Houston began on January 20, 1969. Of the 133 individuals chosen as the survey sample, 34 were eliminated for various reasons -- mechanical incompatibility between the volunteer's automobile and the Tachograph instrument, failure of individuals to report for the installation, mechanical condition of car, etc. Of the 99 actual installations made, seven did not provide usable information because of mechanical failures either in the vehicle or the Tachograph.

TABLE A-2
RECRUITING PARTICIPANTS

<u>ORGANIZATION</u>	<u>QUESTIONNAIRES DISTRIBUTED</u>	<u>VOLUNTEERS</u>	<u>SURVEY SAMPLE</u>
Murphy Ind.	400	26	10
Hughes Tool	100	14	9
Anheuser-Busch	400	29	10
Humble Oil	400	118	20
Houston Chronicle	700	76	10
Continental Emsco	75	14	10
Dresser Systems	200	15	10
AMF Tuboscope	100	32	20
American General Ins.	200	30	14
Brown & Root	200	75	10
Phillips Petroleum	100	20	10
TOTALS	2875	449	133

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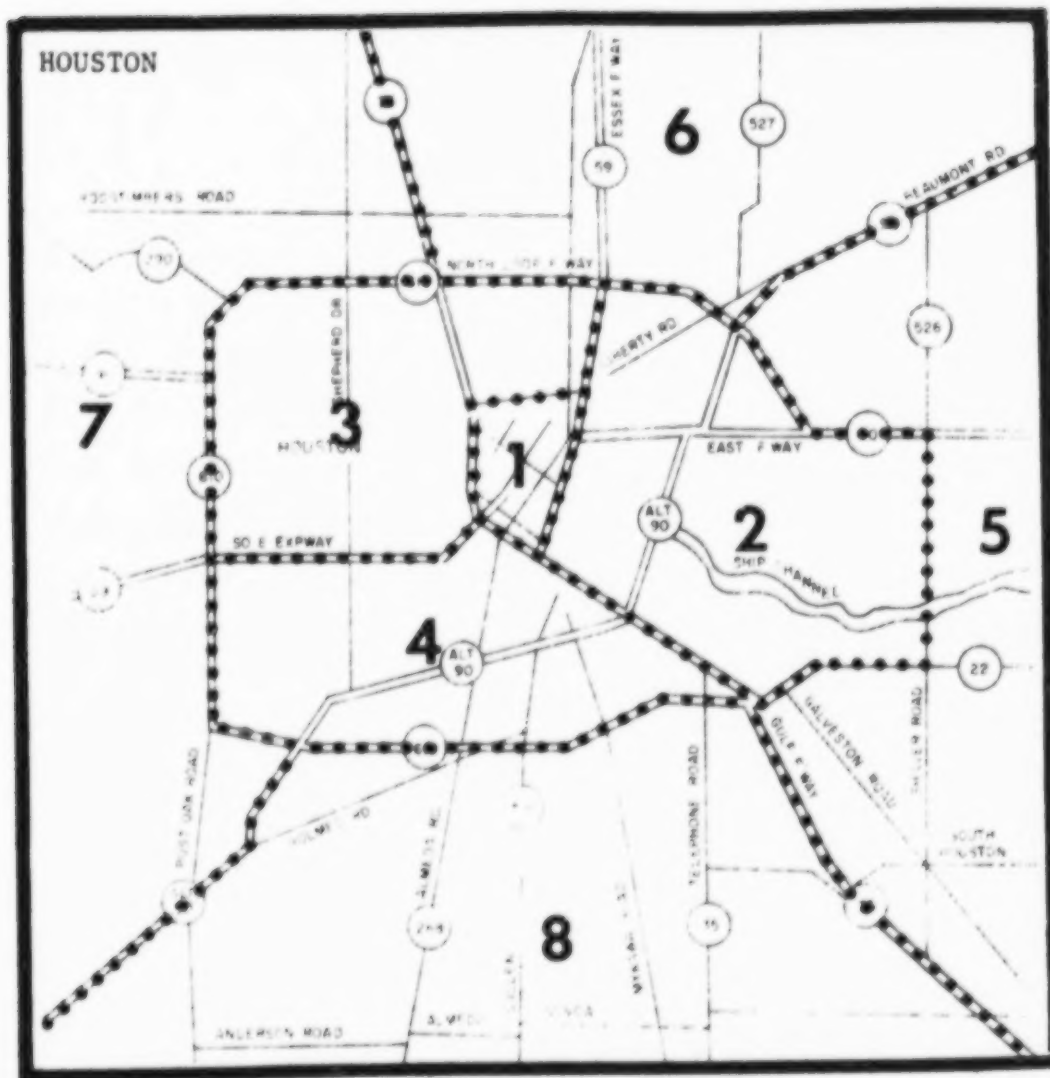


FIGURE A-1

HOUSTON DRIVING PATTERNS SURVEY

SURVEY ZONES

BIBLIOGRAPHIC DATA SHEET		1. Report No. CRC-APRAC-CAPE-10-68-2	2.	3. Recipient's Accession No.
4. Title and Subtitle A Survey of Average Driving Patterns in the Houston Urban Area			5. Report Date Aug 29, 71	
7. Author(s) R.L. Lamoureux, K. Hirschinger, D.H. Kearin			8. Performing Organization Rept. No. T/A-(L)-4119/001/00	
9. Performing Organization Name and Address System Development Corporation 2500 Colorado Avenue Santa Monica, California 90406			10. Project/Task/Work Unit No. CRC-APRAC-CAPE-10-68	
12. Sponsoring Organization Name and Address Coordinating Research Council, Inc., 30 Rockefeller Plaza, New York, New York 10020, and Environmental Protection Agency, 411 West Chapel Hill St. Durham, North Carolina			11. Contract/Grant No. PH 22-68-56	
13. Type of Report & Period Covered Final -- Houston			14.	
15. Supplementary Notes Released to the public August 1971				
16. Abstracts This study was to survey the characteristic use patterns of privately operated automobiles in the Houston urban area. The purpose was to obtain data necessary to develop a composite average driving pattern that would serve as a basis for designing new test cycles for vehicle emission control devices.				
17. Key Words and Document Analysis. 17a. Descriptors Air Pollution Limit Cycles Vehicular Traffic Control Emission				
17b. Identifiers/Open-Ended Terms Houston				
17c. COSATI Field/Group 13B; 13F				
18. Availability Statement Releasable to the public		19. Security Class (This Report) UNCLASSIFIED		21. No. of Pages 102
		20. Security Class (This Page) UNCLASSIFIED		22. Price \$3.00